STEELHEAD RESTORATION AND MANAGEMENT PLAN FOR CALIFORNIA

DEPARTMENT OF FISH AND GAME

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Cover: Summer Steelhead © Daniel W. Gotshall

State of California
The Resources Agency
Department of Fish and Game

STEELHEAD RESTORATION AND MANAGEMENT PLAN FOR CALIFORNIA

by

Dennis McEwan
Associate Fishery Biologist
Inland Fisheries Division, Sacramento

and

Terry A. Jackson
Associate Fishery Biologist
Inland Fisheries Division, Sacramento

Under the Supervision of

Forrest Reynolds
Assistant Chief
Inland Fisheries Division

and

Tim Curtis
Senior Fishery Biologist
Inland Fisheries Division

". . . we must constantly keep in mind that variation, i. e., deviation from the norm is one of the most marked characteristics of animal life. And of the vertebrates, the trouts are among the most variable of all. Further, of the trouts the steelhead is one of the most variable forms."

Leo Shapovalov and Alan Taft, 1954

". . . we do not imply that it is evil to enjoy lox, calamari, and caviar, for carnivory is not inherently immoral. It is only excess that is offensive to nature. And when we destroy the ability of species to survive and to maintain their ecological position, when we destroy their habitats and their capacity to evolve, that is excess."

Nelson and Soule, 1987

FOREWORD

On behalf of the California Department of Fish and Game, I am pleased to present our report, *Steelhead Restoration and Management Plan for California.* This document will serve as the blueprint for the Department's efforts to restore this prized, and oftentimes overlooked, resource.

Restoration of California's anadromous fish populations is mandated by *The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 (SB 226 1)* which states that it is a policy of the State to significantly increase the natural production of salmon and an integral component of, this Action Plan. The Steelhead Plan identifies the life history requirements and needs of an important element of Central Valley anadromous fish ecosystems.

The need to quickly develop and implement a statewide steelhead restoration plan was heightened by the precipitous decline of California's naturally spawning steelhead populations. A rough estimate of the total statewide population is 250,000 adults, less than half the population of 30 years ago. The major factor causing the steelhead population decline, as identified in this document, is freshwater habitat loss and degradation.

The decline of naturally spawning steelhead stocks has prompted the National Marine Fisheries Service (NMFS) to undertake a status review to determine if they warrant listing under the Endangered Species Act (ESA). Implementation of the Steelhead Plan will hasten recovery and may prevent more drastic actions mandated by the Federal ESA. The *Central Valley Project Improvement Act* is another Federal law that addresses restoration of naturally spawning steelhead stocks. The Act establishes funds and water for fish and wildlife restoration in the Central Valley and directs the Secretary of Interior to develop and implement a program to double the natural production of anadromous fish in Central Valley rivers and streams.

This plan is not a single species, stand-alone document that ignores other native aquatic organisms and other portions of the ecosystem. It provides guidelines for steelhead restoration and management that can be integrated into current and future planning for specific river and stream systems. It identifies requirements specific to steelhead and is intended to augment current anadromous fish restoration plans. The Steelhead Plan recognizes that restoration of California's steelhead populations requires a broad approach that emphasizes ecosystem restoration.

As an example of how the plan can be factored into other planning processes, the Department, along with the Resources Agency and several other agencies and organizations, has recently embarked on the *Coastal Salmon Initiative, an* ambitious plan to protect and restore salmon and steelhead habitat along the coastal areas of northern California. The Steelhead Plan identifies <u>what</u> is needed for steelhead in this area, yet does not provide specifics on <u>how</u> to accomplish these needed measures. Elements of the Steelhead Plan can be easily included in the *Coastal Salmon Initiative*, which will provide the specifics on how these restoration measures for steelhead can be accomplished. Thus, the two plans, rather than being two stand-alone plans that attempt to address the same problems, are dependent on each other.

Implementation of actions specified in the Steelhead Plan will reverse the decline in steelhead populations. Restoring California's steelhead populations would provide the following benefits to California citizens:

> In 1991, there were an estimated 99,700 steelhead anglers in California, which is substantially less than that estimated in the early 1980s. This decline in angler numbers mirrors the decline in steelhead numbers. A benefit of the project will be improved angling opportunities for steelhead and increased participation in the sport.
>
> Doubling California's steelhead populations would result in an estimated 37.5 million dollars annually to the State's economy from sport fishing revenue.
>
> Steelhead are an important component of the State's diverse wildlife heritage. They are a good indicator of the health of the aquatic environment because they require clear, clean water, and they use all portions of a river system. As such, they provide an important benefit to the quality of life for all California citizens.

Severe population declines, potential listing under the ESA, fulfillment of legislative mandates, and our Public Trust obligations argue for early implementation of the Steelhead Plan. As always, the overall success of our efforts hinges upon the encouragement and participation of the citizens of this State. The Department welcomes all suggestions from, and the involvement of, anyone that shares our view of a healthy, sustainable future for fish and wildlife in California.

C. F. Raysbrook
Interim Director

February 1996

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Steelhead are an important and valued resource to California's citizens and are an important component of the vast biodiversity of the State. Like many of California's anadromous fish resources, steelhead are declining. Decline of steelhead populations is but one aspect of the present statewide decline in biodiversity, caused by California's burgeoning human population and the ever-increasing demand on natural resources.

This plan focuses on restoration of native and naturally produced (wild) stocks because these stocks have the greatest value for maintaining genetic and biological diversity.

Goals for steelhead restoration and management are 1) increase natural production, as mandated by The Salmon, *Steelhead Trout, and Anadromous Fisheries Program Act of 1988, so* that steelhead populations are self-sustaining and maintained in good condition and 2) enhance angling opportunities and non-consumptive uses.

Strategies to accomplish these goals are 1) restore degraded habitat 2) restore access to historic habitat that is presently blocked 3) review angling regulations to ensure that steelhead adults and juveniles are not over-harvested 4) maintain and improve hatchery runs, where appropriate and 5) develop and facilitate research to address deficiencies in information on fresh water and ocean life history, behavior, habitat requirements, and other aspects of s teelhead biology.

Status

Rough estimates place the total statewide population at 250,000 adults, less than half the population of 30 years ago. The decline of California steelhead appears to be part of a more prevalent coastwide steelhead decline. This decline has prompted the National Marine Fisheries Service to undertake a status review to determine if steelhead warrant listing under the Endangered Species Act. The major factor causing the decline in California is freshwater habitat loss and degradation. This has resulted mainly from three factors: inadequate stream flows, blocked access to historic spawning and rearing areas due to dams, and human activities that discharge sediment and debris into watercourses.

The historic range of steelhead on the north coast (north of San Francisco Bay) has not been reduced as drastically as it has in other areas of the State. Consequently, this area has the greatest amount of remaining steelhead habitat in the State and the most abundant populations. The Klamath-Trinity river system supports the greatest number of steelhead in California. However, these stocks have declined from an estimated run size of 283,000 adults in the early 1960s to about 150,000 in the early 1980s. Steelhead runs in north coast drainages are comprised mostly of wild fish, although the percentage of wild fish appears to have decreased in recent years. Adverse impacts to north coast stocks are mainly from land-use activities, primarily timber harvest and agriculture, and water diversion, gravel mining, and predation by recently introduced squawfish.

Steelhead ranged throughout the tributaries of the Sacramento and San Joaquin rivers prior to dam construction, water development, and watershed perturbations of the 19th and 20th centuries. Populations have been most severely affected by dams blocking access to the headwaters of all the major tributaries, consequently, most runs are maintained through artificial production. The average annual run size in the Sacramento River system above the mouth of the Feather River in the 1950's was estimated to be 20,540 fish. The annual run size for the total Sacramento River system in 1991-92 was probably less than 10,000 adult fish. The decline of Central Valley naturally produced steelhead has been more precipitous than that of the hatchery stocks: numbers of wild steelhead above Red Bluff Diversion Dam (RBDD) on the Sacramento River have decreased from an average annual run size of roughly 12,900 in the late 1960's to approximately 1,100 in 1993-94. Wild stocks are mostly confined to upper Sacramento River tributaries such as Deer, Mill, and Antelope creeks and the Yuba River.

Southern steelhead (those occurring south of San Francisco Bay) were formerly found in coastal drainages as far south as the Santo Domingo River in northern Baja California and were present in many streams and rivers of southern California. Today, Malibu Creek in Los Angeles County is the southern most stream containing a known spawning population. Southern steelhead are the most jeopardized of all of California's steelhead populations. Population numbers have declined drastically in nearly all streams where they exist, and runs have been extirpated from many others. Of 122 streams south of San Francisco Bay known to have contained a steelhead population, 47% had populations with reduced production from historical levels and 33 % no longer supported populations. Major adverse impacts to southern steelhead are from urbanization and water impoundment and diversion.

Watershed Protection and Restoration

Land-use activities associated with logging, road construction, urban development, mining, livestock grazing, and recreation have reduced fish habitat quantity and quality by changing streambank and channel morphology, altering water temperatures, degrading water quality, and blocking access to spawning areas. DFG supports recent initiatives to restore and maintain anadromous fish habitat on Federal and private lands.

Stream Restoration

There are many streams in California where water has been over-appropriated. The recent drought has shown that there is little water to spare for instream uses in many areas of the State. DFG utilizes several provisions and laws to protect and maintain instream flows for the benefit of fish and wildlife, although protection of instream flows is frequently inadequate. The Klamath River below Iron Gate Dam, the Sacramento River below Shasta

Dam, the American River below Folsom Dam, the San Joaquin River below Friant Dam, and the Santa Ynez River below Bradbury Dam are a few examples of former and present steelhead waters where severe environmental problems have resulted because of insufficient releases from reservoirs. Although there have been several favorable court decisions affirming the protection of fish and wildlife under the Public Trust Doctrine, those resources held in trust in many areas of the State continue to decline. DFG needs a more effective means to identify, maintain, and achieve adequate flows for steelhead throughout their range.

Further protections from suction dredging impacts may be necessary for some steelhead populations. Stream bank alteration permits for gravel mining should include measures to insure that public trust values are protected.

Estuaries can be important rearing areas for juvenile steelhead, especially in small coastal tributaries. Mechanical breaching of sandbars to drain lagoons and estuaries can have detrimental effects on survival of juvenile steelhead. Methods to allow regulation of lagoon water levels which alleviate the need for breaching need to be developed and implemented.

Increased development and incompatible land uses can negate existing protections for steelhead habitat. Therefor, acquiring lands to protect critical stream reaches should be a high priority. Priority should be given to acquisition of riparian lands that have water rights, stream reaches to support depressed native stocks, and estuaries.

Natural and Artificial Production

Although many artificial propagation programs have succeeded in producing fish for harvest, they have generally not produced a sustained increase in the abundance of wild fish or fully mitigated for water development impacts. There is evidence that impacts to wild populations from hatchery supplementation may be contributing to their decline. Two main concerns regarding the effects of hatchery supplementation programs on wild steelhead genetics are loss of genetic diversity and reduction in fitness to the natural environment.

Under State policy, natural production is the foundation for steelhead management and restoration. Artificial production will be limited to areas where it already occurs, where it is necessary to prevent the extinction of a native run, or where the native population has already become extirpated and the habitat is irrevocably altered.

Existing hatchery and rearing programs will be operated to minimize impacts to natural stocks to the maximum extent possible. To provide a solid foundation to begin managing to protect natural stocks, DFG needs a reliable means to differentiate wild fish from hatchery fish. For this reason, all hatchery production will be marked prior to release. The Stock Management Policy will be strictly adhered to by all agents of the DFG.

Angling

In 1991, there were an estimated 99,700 steelhead anglers in California. It is estimated that sport fishing revenues could generate an additional 37.5 million dollars per year to the State's economy if California's steelhead populations are doubled.

Limited information on steelhead sport harvest rates suggests that over-exploitation of wild stocks is not occurring on a widespread basis and is not causing the general decline, therefore, a statewide selective harvest regulation or an annual bag limit is not warranted.

Management Objectives

North Coast

Management focus will be on maintaining and increasing population abundance, with principal emphasis on naturally produced stocks. Management efforts will be directed toward minimizing the impacts from watershed disturbances, preventing new disturbances, restoring instream habitat, and increasing summer steelhead populations.

Population monitoring and implementation of new angling regulations and habitat protection measures are recommended to prevent further declines of summer steelhead populations.

Greater releases from Iron Gate Dam on the Klamath. River are needed. A long-term flow evaluation on the Trinity River will be completed in 1996 and may result in increased releases for fish and wildlife. Watershed and stream restoration activities in the South Fork Trinity River need to be accelerated.

Steelhead production in the Scott and Shasta rivers is constrained by severely degraded habitat conditions from timber harvest and agricultural practices. Improved flows for anadromous fish populations in these rivers are needed.

DFG is developing a restoration plan for salmon and steelhead in the Eel River which will identify specific actions needed for steelhead restoration in this system. DFG and other agencies are investigating the effectiveness of controlling introduced squawfish populations through techniques such as gill netting and seining, electrofishing , explosives, and chemical treatments.

Habitat for naturally spawning steelhead in the Russian River system is severely degraded. Instream flow requirements for salmon and steelhead need to be determined. When the cumulative impact analysis of existing and proposed diversions is completed, DFG should make the appropriate recommendations to the State Water Resources Control Board (SRWCB) so that necessary instream flows are provided.

Central Vallev

Management focus for Central Valley steelhead is to recover native and wild populations and restore hatchery-maintained runs.

The Sacramento River below Keswick Dam is beset with many of the ecological problems associated with highly regulated rivers. This river yields 35 % of California's water supply and provides for the largest portion of the State's sport and commercial salmon catch. These two incongruous functions lie at the heart of California's present water controversy. Identified restoration measures for the mainstem include correcting fish passage and fish screening problems at the Glenn Colusa Irrigation District Diversion, Red Bluff Diversion Dam, and small agricultural diversions; rerouting the Colusa Drain; and cleanup of Iron Mountain Mine.

Mill, Deer, and Antelope creeks have the best potential of all Central Valley streams for restoring wild steelhead populations. These streams are similar in that they have relatively pristine, well-protected upper reaches with ample spawning and rearing habitat, and they suffer from inadequate flows in the lower reaches. A solution to inadequate flows in Mill Creek is being implemented: ground water is being exchanged for surface flows, with funds provided to the diverter to pay power costs for pumping. A monitoring program funded by *Steelhead Catch Report-Restoration Card* revenues was recently implemented in Mill and Deer creeks to assess adult steelhead numbers.

The Yuba River supports the largest, naturally reproducing population of steelhead in the Central Valley. DFG has recommended temperature and flow regimes to the SWRCB to maintain and restore the anadromous fisheries. DFG will continue to manage the Yuba River as a wild steelhead fishery.

The steelhead population in the American River is almost entirely supported by Nimbus Hatchery. Over the past decade the run has declined significantly, probably due to adverse water temperature conditions, rapid flow fluctuations, inadequate water releases from Nimbus Dam, increased CVP and SWP water exports, and the 1986-92 drought. Measures to restore steelhead populations include: adoption of adequate minimum flows and flow fluctuation standards by the SWRCB; establishment of a minimum storage level for Folsom Reservoir; and correcting the water temperature problem at Nimbus Hatchery.

Natural production of steelhead in the Central Valley will continue to be limited due to inaccessibility of the headwaters. A hatchery program needs to be implemented if restoration of steelhead is to be achieved for the San Joaquin River system.

South Coast

Management focus will be on recovering southern steelhead stocks from impending extinction and this will be the highest priority for DFG's steelhead management.

Water development has caused severe habitat impacts to the Carmel River, including dewatering, a broadening of the channel, and loss of riparian habitat. A new dam has been proposed to increase the water supply in the region. The SWRCB should require identified measures to restore and maintain the steelhead population and should retain jurisdiction over the dam project to ensure that public trust values are protected.

DFG will seek interim and permanent flo'w regimes from Lake Cachuma on the Santa Ynez River to restore steelhead runs that have been eliminated by water development. The feasibility of providing passage around Bradbury Dam should be investigated.

Constructing a fishway on the Robles Diversion Dam on the mainstem Ventura River would restore access to about 10 miles of spawning and rearing habitat. DFG should begin discussion with responsible agencies regarding the removal or modification of Matilija Dam to allow access to about 10 additional miles of headwater spawning and rearing areas on Matilija Creek.

Recent construction of a fishway on the Vern Freeman Diversion should restore access to Sespe Creek, the largest and most pristine tributary to the Santa Clara River. Results of fish trapping at the Diversion facility in 1994 indicate that a viable steelhead population still exists in the Santa Clara River. Instream flow requirements for steelhead need to be investigated.

The major obstacle to restoring the steelhead run on Malibu Creek is Rindge Dam, located about 2.5 miles upstream from the Pacific Ocean. DFG is currently investigating the feasibility of removing this dam.

Conclusion

Watershed restoration and protection, providing adequate streamflows, and restoring access to headwaters need to be the focal points for DFG's efforts to restore steelhead populations. Establishment of conditions, constraints, and practices which maintain watershed integrity and stream flows, and restoration of problem areas which continue to degrade or block aquatic habitat, are of the utmost importance to restoring steelhead populations.

Restoration of steelhead populations is intimately tied to the establishment of a new ethic for management of California's rivers and streams - an ethic that places a much higher priority on the continuance of essential physical, biological, and ecological processes in rivers that are regulated or proposed for development. Without this, aquatic habitat will continue to degrade, steelhead and other species will continue to decline, and there will be continued impasses on water usage and development.

PART I: INTRODUCTION

Half-pounder steelhead from the Klamath River.

PURPOSE AND GOALS

Steelhead rainbow trout *(Oncorhynchus mykiss)* were once abundant in California's coastal and Central Valley rivers and streams. Like many of California's anadromous fish resources, steelhead numbers are declining. Rough estimates place the total statewide population at about 250,000 adults, probably less than half of the population of 30 years ago. An accurate estimate of the statewide population is not available, but there are reliable estimates on select streams and rivers throughout the state. All populations for which there are good estimates show a declining trend.

The decline of California's steelhead populations is inextricably linked to the increase in the State's human population. Past and present development activities in rivers and watersheds, together with ever-increasing development of the State's water resources, have affected every river system and watershed in the State to some degree. The magnitude of these effects vary: the Smith River is fairly pristine, well protected, and has one of the healthiest steelhead populations in the State; the Carmel River, on the other extreme, did not flow to the ocean for four years during the recent drought because of surface diversions and excessive groundwater pumping, and its native steelhead population is at a critically low level. The recent six-year drought undoubtedly contributed to the decline of many populations, but most populations were already in decline prior to the onset of the drought. The drought also foreshadowed what may occur for fish and wildlife if excessive water development became a permanent feature on the California bioscape.

Efforts to manage steelhead and reverse this decline have been hampered by an acute lack of information, particularly status and basic life history characteristics of individual stocks. The need for information to manage commercial and sport harvest of Pacific salmon stocks has intensified in recent years. This has led to a redirection of the California Department of Fish and Game's (DFG) anadromous fisheries research and management to meet these needs. Consequently, steelhead research and management have been greatly reduced since the 1940's and 50's when DFG produced such classic studies as Shapovalov and Taft's (1954) life history study on Scott and Waddell creeks and Hallock et al. (1961) evaluation of stocking of hatchery-reared steelhead in the Sacramento River.

Restoration of California's anadromous fish populations is mandated by *The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 (SB 2261)* which states that it is a policy of the State to significantly increase the natural production of salmon and steelhead by the end of the century. SB 2261 directs DFG to develop a program that strives to double naturally spawning anadromous fish populations by the year 2000.

To ensure that steelhead management and restoration did not get lost within salmon management in this new program, several angling and conservation organizations urged DFG to establish a Steelhead Project. Thus, the Steelhead Management and Restoration Project was established in 1991. The purpose of this project is to assure the maintenance, restoration, and enhancement of California's steelhead stocks. The project is responsible for statewide coordination of DFG's steelhead management, research, and restoration activities. A high priority of the project is the development and implementation of the Steelhead Restoration and Management Plan. This document will be the blueprint for future DFG steelhead management and will provide direction for the restoration and maintenance of California's steelhead populations.

Restoration of California's anadromous fish populations requires a broad approach that emphasizes ecosystem restoration. Basin planning, which addresses problems and solutions on a stream system/watershed basis, is necessary to identify restoration activities within a particular stream system that will benefit the aquatic ecosystem and insure that measures to benefit one species do not damage others. For some areas of the State, planning efforts for anadromous fish restoration have been accomplished or are presently underway. In some river systems, specific restoration measures that will benefit steelhead populations have already been identified and are incorporated into this Plan.

This document provides guidelines for steelhead restoration and management, to be integrated into current and future planning processes for specific river and stream systems. It also identifies those needs specific to steelhead and is intended to augment current anadromous fish restoration plans. Specific action items are identified where urgency is needed to prevent the extirpation of wild populations. This document is not intended to be a plan that implements steelhead restoration measures at the expense of other native aquatic organisms and other portions of the ecosystem.

This plan focuses on restoration of native and wild stocks. It is these stocks which have the greatest value for the species as a whole, in terms of maintaining genetic and biological diversity. Also, several of California's native steelhead stocks have declined to such low levels that listing under the Endangered Species Act is likely unless actions are implemented now to prevent further declines.

Goals for steelhead restoration and management are 1) increase natural production, as mandated by The *Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988, so* that steelhead populations are self-sustaining and maintained in good condition and 2) enhance angling opportunities and non-consumptive uses.

Strategies to accomplish these goals are:

1. Restore degraded habitat.

2. Restore access to historic habitat that is presently blocked.

3. Review angling regulations to ensure that steelhead adults and juveniles are not over-harvested.

4. Maintain and improve hatchery runs, where appropriate.

5. Develop and facilitate research to address deficiencies in information on fresh water and ocean life history, behavior, habitat requirements, and other aspects of steelhead biology.

Successful accomplishment of these goals will require that adequate monitoring and assessment activities are implemented to collect baseline information, assess population trends, and evaluate success of restoration activities.

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[1] For purposes of this report, the following definitions are used:

Native stocks: those populations that are indigenous to a specific river system or stream.
Natural or *Wild* stocks: those populations that are self-sustaining and which spawn naturally, regardless of origin.
Natural production: Fish production from natural (in-river) spawning and rearing.
Artificial or *Hatchery production.* Fish production from hatchery or rearing facilities.

CURRENT MANAGEMENT AND POLICIES

With the passage of the *Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988,* management emphasis has been placed on restoration of depleted natural stocks. Programs currently in place to help restore steelhead populations consist chiefly of projects to restore habitat. Current management direction is provided by several Fish and Game Code sections, Fish and Game Commission (FGC) Policy, and DFG policies.

Salmon, Steelhead Trout, and Anadromous Fisheries Program Act

This Act was passed by the California legislature, signed by Governor Deukmejian, and chaptered into the Fish and Game Code in 1988 (Section 6900 et. seq.). Its intent was to implement the recommendations of the California Advisory Committee on Salmon and Steelhead Trout (CACSST) to conserve and restore the anadromous fisheries resources of the State. The CACSST is a citizen's advisory committee created by the state Legislature in 1983 to develop a strategy for the conservation and restoration of salmon and steelhead resources in California. It consists of representatives from commercial and sport fishing organizations, native Americans, aquatic scientists, and public interest groups. The Act established the Salmon and Steelhead Trout Restoration Program within DFG, whose purpose is to "develop a plan and program that strives to double the current [1988] natural production of salmon and steelhead".

The legislation also found that:

> Natural production of steelhead had declined, primarily as a result of lost stream habitat, and much of the loss has occurred in the Central Valley.
>
> Protection and enhancement of the naturally spawning salmon and steelhead would provide a valuable public resource to residents and would have a large statewide economic benefit.
>
> Proper salmon and steelhead resource management requires maintaining adequate levels of natural, as compared to hatchery, spawning and rearing. Reliance upon hatchery production of salmon and steelhead is at or near the maximum percentage that it should occupy in the mix of natural and artificial hatchery production in the State. If both hatchery production and natural production are feasible alternatives for increasing salmon and steelhead numbers in specific situations, preference shall be given to natural production.

Protection and restoration must be accomplished primarily through the improvement of stream habitat.

The Act also declared that it is a policy of the State:

- to significantly increase the natural production of salmon and steelhead trout by the end of this century.

- to recognize and encourage the participation of the public in mitigation, restoration, and enhancement programs in order to protect and increase natural spawning salmon and steelhead resources.

- that existing natural salmon and steelhead habitat shall not be diminished further without offsetting impacts of the lost habitat.

The development and ‘implementation of this management plan is authorized pursuant to this Act.

Steelhead Rainbow Trout Policy

This policy of the California Fish and Game Commission (FGC) was recently updated and amended. The policy recognizes the need to protect genetic integrity and habitat of all stocks and places management emphasis on natural stocks. The policy declares:

Management of steelhead will be directed towards protection and maintenance of populations and genetic integrity of all identifiable stocks.

Juvenile steelhead rescued from desiccating streams must be returned to their natal stream. Steelhead rescue will only be allowed when fish can be held until habitat conditions improve or they can be released immediately in other areas of their natal stream.

Restoration and acquisition plans will be developed and implemented to safeguard critical habitats such as estuaries, lagoons, and spawning and rearing areas, and to secure necessary instream flows.

Existing steelhead habitat shall not be diminished further without offsetting mitigation of equal or greater long-term habitat benefits. DFG will oppose any development or project which will result in irreplaceable losses. Artificial production will not be considered appropriate mitigation for loss of wild fish or their habitat.

Sport fishing for adult and juvenile steelhead will only be permitted where DFG has determined that harvest will not harm existing wild populations or impair adequate returns of adults for sport fishing and spawning.

Resident fish will not be planted in drainages of steelhead waters if DFG has determined that it will interfere with steelhead populations.

Salmon and Steelhead Stock Management Policy

It is the policy of DFG to maintain the genetic integrity of all identifiable stocks of salmon and steelhead in California. Each salmon and steelhead stream shall be evaluated by DFG and the stocks classified according to their probable genetic source and degree of integrity.

A classification system shall be employed to define stocks and the role of artificial production for the management of each salmon and steelhead stream. This classification system will guide management and restoration efforts, and policies relating to artificial production will also be compatible with this classification system.

The salmon and steelhead stocks stream management goal shall manage streams for the following appropriate stock and only those stocks may be placed in the stream (each term is progressively inclusive of the preceding terms):

1. Endemic - Only historical naturally reproducing fish originating from the same stream or tributary.

2. Naturallv reproducing stocks within drainage - Naturally reproducing stocks from the drainage of which the stream is part.

3. Hatchery stocks within basin - Stocks which may include hatchery produced fish from streams within the drainage.

4. Naturally reproducing stocks from out of basin - Naturally reproducing stocks from streams outside the basin of which the stream is part.

5. Hatchery stocks out of basin - Stocks which may include hatchery produced fish from streams outside the basin.

6. Any stock - Any stock which appears to exhibit characteristics suitable for the stream system.

Artificial production limitations shall be defined according to the following terms:

1. None - No artificial production or fish planting permitted; management shall be for natural production.

2. Supplementary - Artificial production is less desirable than natural production and is allowed only to the extent that it provides for full stocking of the stream.

3. Complementary - Artificial production is as important for fishery management purposes as natural production and may be used on a permanent basis to complement natural production.

4. Hatchery - Managed principally for hatchery production with natural production protected but considered secondary.

Trout and Steelhead Conservation and Management Act of 1979.

This Act declares that it is a policy of the State to:

1) Establish and maintain wild trout and steelhead stocks in suitable waters of the state.

2) Establish angling regulations designed to maintain wild trout and steelhead

also will oppose development proposals unless project mitigation assures there will be "no net loss" of either wetland habitat values or acreage. Primary consideration for compensation for adverse impacts will be given to in *kind, on site* mitigation.

Cooperative Salmon and Steelhead Rearing Facilities and Cooperatively Operated Rearing Programs For Salmon and Steelhead Policies.

Section 1200 et. seq. of the Fish and Game Code authorizes DFG to enter into agreements with counties, nonprofit groups, and private persons for the management and operation of rearing facilities for salmon and steelhead. All such agreements shall be in accordance with the policies of the FGC and the criteria of DFG which govern the operation under such agreements. The purpose of the rearing facilities is to provide additional fishing resources and to augment natural runs. This section also authorizes DFG to provide surplus eggs and fish to the rearing facility. This section prohibits the release of fish reared at these facilities into waters south of Point Conception because ocean conditions, primarily water temperatures, *are* not conducive to Salmonid survival in most years.

The FGC policy on *Cooperatively Operated Rearing Programs* states that the bulk of the State's salmon and steelhead resources shah be produced naturally and that the State's goals of maintaining and increasing natural production take precedence over the goals of cooperatively operated rearing programs. This policy also requires that:

- only those fish surplus to the needs of DFG's programs shall be utilized and allocation shall be based on past performance and DFG's evaluation of the potential of proposed new programs.

- a written proposal and a five-year management plan must be submitted to DFG for evaluation and approval.

- fish raised in these programs shah not be stocked in, or broodstock captured from, waters where DFG has determined that adverse effects to native fish populations or other aquatic species may result.

OVERVIEW OF STEELHEAD BIOLOGY

LIFE HISTORY

Steelhead are the anadromous form of rainbow trout, a Salmonid species native to western North America and the Pacific coast of Asia (Fig. 1). In North America, steelhead are found in Pacific Ocean drainages from southern California to Alaska. In Asia, they are found on the east and west coast of the Kamchatka Peninsula, with scattered populations on the mainland (Burgner et al. 1992). In California, known spawning populations are found in coastal rivers and streams from Malibu Creek in Los Angeles County to the Smith River near the Oregon border, and in the Sacramento River system. The present distribution of steelhead in California has been greatly reduced from historical levels (Fig. 2).

Steelhead are similar to some Pacific salmon in their ecological requirements. They are born in fresh water, then emigrate to the ocean where most of their growth occurs, and then return to fresh water to spawn. Unlike Pacific salmon, steelhead do not necessarily die after spawning. Post-spawning survival rates are generally quite low, however, and vary considerably between populations.

In California, most steelhead spawn from December through April in small streams and tributaries where cool, well oxygenated water is available year-round. The female selects a site where there is good intergravel flow, then digs a redd and deposits eggs while an attendant male fertilizes them. The eggs are then covered with gravel when the female begins excavation of another redd just upstream.

The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51° F (Leitritz and Lewis 1980). Fry emerge from the gravel usually about four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954).

The newly emerged fry move to the shallow, protected areas associated with the stream margin (Royal 1972; Barnhart 1986). They soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954). Most juveniles inhabit riffles but some of the larger ones will inhabit pools or deeper runs (Barnhart 1986).

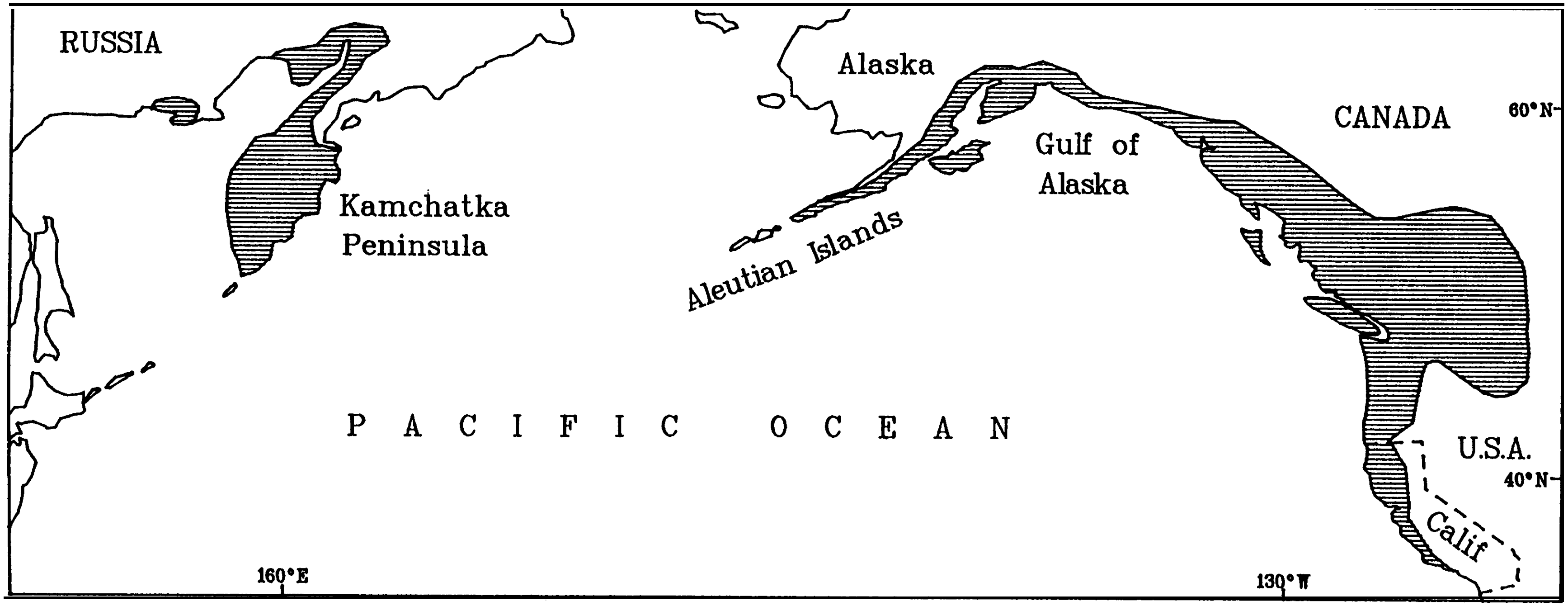

Figure 1. Distribution of steelhead rainbow trout, *Oncorhynchus mykiss* (modified from Burgner et al. 1992).

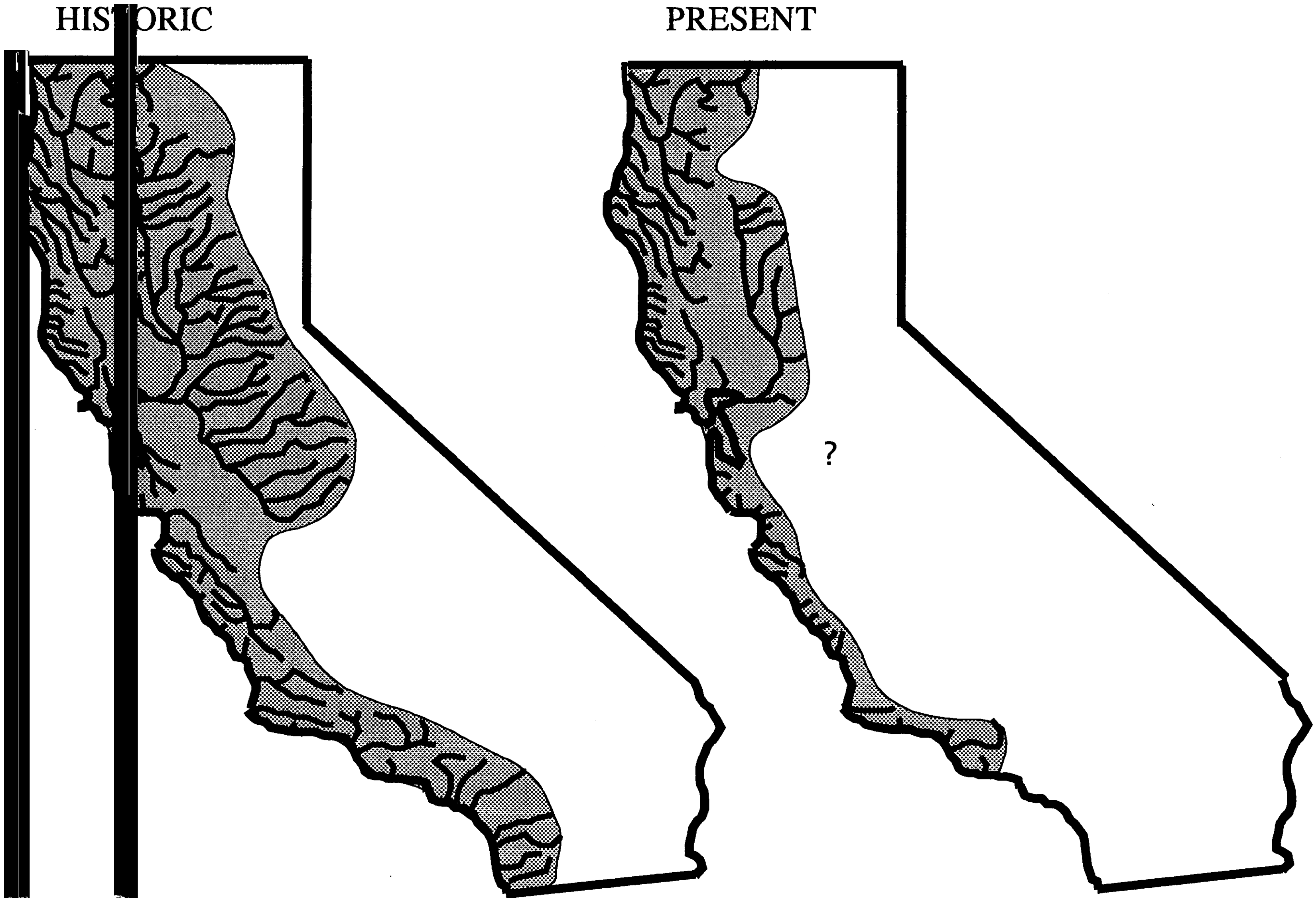

Figure 2. Historic and present distribution of steelhead in California.

The life history of steelhead differs from that of Pacific salmon principally in two aspects: juveniles have a longer fresh water rearing requirement (usually from one to three years) and both adults and juveniles are much more variable in the amount of time they spend in fresh and salt water. Throughout their range, steelhead typically remain at sea for one to four growing seasons before returning to fresh water to spawn (Burgner et al. 1992). Boydstun (1977) found that most Gualala River steelhead migrated to sea as two-year old fish and returned after spending two years in the ocean. In Scott and Waddell creeks, the majority of adults returning to the stream to spawn had spent two years in fresh water and one or two years in the ocean. However, steelhead from these streams occasionally exhibited other life history patterns: scale analysis of adults indicated that they spent from one to four years in fresh water and from one to three years in the ocean (Shapovalov and Taft 1954). Steelhead do not necessarily migrate at any set age. Some individuals will remain in a stream, mature, and even spawn without ever going to sea, others will migrate to sea at less than a year old, and some will return to fresh water after spending less than a year in the ocean.

There are two basic life history types of steelhead: *stream-maturing* steelhead, which enter fresh water with immature gonads and consequently must spend several months in the stream before they are ready to spawn; and *ocean-maturing* steelhead, which mature in the ocean and'spawn relatively soon after entry into fresh water (Peggy Busby, Fishery Research Biologist, National Marine Fisheries Service, pers. comm.). This corresponds to the accepted classification which groups steelhead into two seasonal "races": summer and winter steelhead (Withler 1966; Royal 1972; Roelofs 1983; Barnhart 1986; Burgner et al. 1992). Stream-maturing steelhead (summer steelhead) typically enter fresh water in spring, early summer, and possibly fall. They ascend to headwater tributaries, hold over in deep pools until mature, and spawn in late fall and winter. Ocean-maturing steelhead (winter steelhead) typically begin their spawning migration in fall and winter and spawn within a few weeks to a few months from the time they enter fresh water. Ocean-maturing steelhead generally spawn January through March, but spawning can extend into spring and possibly early summer months. In the Rogue River, spawning of stream-maturing and ocean-maturing steelhead is spatially and temporally segregated (Everest 1973). Little is known about spawning time and location of California stream-maturing steelhead populations (Roelofs 1983).

This classification is mostly one based on behavioral and physiological differences and does not reflect genetic or taxonomic relationships (Allendorf 1975; Allendorf and Utter 1979; Behnke 1992). The degree of genetic similarity is mostly a reflection of geographical relationships; that is, summer steelhead' occupying a particular river system are more genetically similar to winter steelhead of that system than they are to summer steelhead in other systems. Allendorf (1975) found that summer steelhead from several coastal streams in Washington were genetically indistinguishable from coastal winter steelhead of the same streams, but showed no genetic affinities with inland (upper Columbia River) summer steelhead.

Rainbow trout have also been classified on the basis of anadromy. In the past, steelhead and non-anadromous (resident) rainbow trout have been grouped as two different subspecies and even different species by early researchers (Allendorf 1975). However, little or no morphological or genetic differentiation has been found between anadromous and resident forms inhabiting the same stream system[2] (Behnke 1972; Allendorf 1975; Allendorf and Utter 1979; Busby et. al 1993; Nielsen 1994). The conversion of anadromous forms that have become isolated upstream of dams to resident populations (e.g. Whale Rock Reservoir and Redwood Creek populations) is a further indication of the close genetic and taxonomic relationship of these two forms. Anadromous and resident rainbow trout apparently did not arise from two distinct evolutionary lines, but rather the two forms have given rise to each other independently (Behnke 1992).

Behnke (1972), Allendorf (1975)) Allendorf and Utter (1979), and Wilson et al. (1985) conclude that rainbow trout cannot be separated taxonomically by timing of return to fresh water (summer vs. winter steelhead) or their tendency for anadromy (steelhead vs. resident rainbow trout). Rather, rainbow trout are taxonomically structured on a geographic basis (coastal vs. inland forms). Similarly, Behnke (1992) identifies two subspecies of North American rainbow trout that exhibit anadromy: coastal rainbow trout (0. *m. irideus)* and Columbia River redband trout (0. *m. gairdneri).* All steelhead populations of 0. *m. gairdneri are* summer steelhead (Behnke 1992; Burgner et. al 1992) and occupy upper Columbia River tributaries east of the Cascades. 0. *m. irideus* is distributed along coastal rivers and streams from California to Alaska and consists of both summer and winter steelhead populations. All steelhead populations in California are 0. *m. irideus* (Behnke 1992).

DFG has traditionally grouped steelhead into seasonal runs according to their peak migration period: in California there are well-defined winter, spring, and fall runs. This

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[1] Summer *steelhead* and *winter steelhead* will be used throughout the remainder of this document to describe the two behavioral types of California steelhead. These terms are synonymous with *stream-maturing* and *ocean-maturing* steelhead, respectively.

[2] Wilson et al. (1985) did however, find differences in mitochondrial DNA sequences between anadromous and resident rainbow trout of the same drainage.

classification is useful in describing actual run timing, but is confusing when it is used to further categorize steelhead populations. Seasonal classification does not reflect stock characteristics, spawning strategies, and run overlap between summer and winter steelhead. Also, a seasonal run may be comprised of both summer and winter steelhead. For example, spring-run steelhead in the Eel River system are summer steelhead because they hold-over and do not spawn until the following winter; spring-run steelhead entering southern California streams in spring and early summer are mature and spawn immediately, and thus are winter steelhead. Run timing is a characteristic of a particular stock, but, by itself, does not constitute "race".

rainbow trout and the linkage between the two forms. Busby et. al (1993) state, that for purposes of Endangered Species Act evaluation and implementation, resident rainbow trout and steelhead that share a common gene pool should be considered together as one unit.

HABITAT CRITERIA

Depth. The preferred depth for steelhead spawning is approximately 14 inches and ranges from 6 to 24 inches (Bovee 1978). Fry prefer water approximately 8 inches in depth and utilize water 2 to 14 inches deep, while parr prefer a water depth of 10 inches but utilize water 10 to 20 inches deep (Bovee 1978).

In natural channels, water depth usually does not hinder adult migration because adult steelhead normally migrate during high flows. Depth can become a significant barrier or impedance in streams that have been altered for flood control purposes, especially those that do not have a low flow channel. It has been reported that seven inches is the minimum depth required for successful migration of adult steelhead (Thompson 1972, as cited in Barnhart 1986) although the distance fish must travel through shallow water areas is also a critical factor. Excessive water velocity and obstacles which impede the swimming and jumping ability are more significant in hindering or blocking migration (Barnhart 1986).

Velocity. Water velocities of 10 to 13 ft/s begin to hinder the swimming ability of adult steelhead and may retard migration (Reiser and Bjornn 1979). Steelhead spawn in areas with water velocities ranging from 1 to 3.6 ft/s but prefer velocities of about 2 ft/s (Bovee 1978). The ability to spawn in higher velocities is a function of size: larger steelhead can establish redds and spawn in faster currents than smaller steelhead (Barnhart 1986).

Substrate. Adult steelhead have been reported to spawn in substrates from 0.2 to 4.0 inches in diameter (Reiser and Bjornn 1979). Based on the Bovee (1978) classification, steelhead utilize mostly gravel-sized material for spawning but will also use mixtures of sand-gravel and gravel-cobble[3]. Fry and juvenile steelhead prefer approximately the same size of substrate material (cobble/rubble) which is slightly larger than that preferred by adult steelhead for spawning (gravel) (Bovee 1978). The gravel must be highly permeable to keep the incubating eggs well oxygenated and should contain less than 5 % sand and silt.

Temperature. The preferred water temperature for various life stages of steelhead is well documented (Bovee 1978; Reiser and Bjornn 1979; Bell 1986) (Table 1).

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[3] According to the Unified Soil Classification System, sand is defined as particles with diameters from 0.003 to 0.19 inches, gravel is from 0.19 to 3 .O inches, and cobble is from 3 .O to 11.8 inches.

Table 1. Preferred water temperatures for various steelhead life history stages.

Life History Stage	**Temperature Range (°F)**
Adult migration	46 to 52
Spawning	39 to 52
Incubation and emergence	48 to 52
Fry and juvenile rearing	45 to 60
Smoltification	< 57

Optimum temperature requirements of steelhead may vary depending on season, life stage, and stock characteristics. Egg mortality begins to occur at 56° F. Steelhead have difficulty extracting oxygen from water at temperatures greater than 70° F (Hooper 1973, as cited in Barnhart 1986). In California, low temperatures are not as much of a concern as high temperatures, especially high temperatures that occur during adult migration, egg incubation, and juvenile rearing.

The temperatures noted in Table 1 are optimal conditions. Rainbow trout are known to exist in relatively high temperature regimes, some of which exceed the preferred temperatures for considerable lengths of time (e.g. steelhead in south coastal streams).

THE STEELHEAD FISHERY

Native Americans utilized salmon and steelhead for subsistence, trade, and ceremonial purposes. Salmon and steelhead were harvested year-round by central coast and Central Valley tribes, and primarily during late summer and fall months by north coast tribes. Nets, spears, traps, and weirs were utilized to capture the fish. Today, Native Americans employ gill nets and, to a lesser extent, dip nets to capture salmon and are limited mostly to the Klamath River system. The large mesh gill nets used in this fishery are targeting salmon, hence the smaller sized steelhead are not taken in large numbers. (Roger Barnhart, Project Leader, National Biological Survey Cooperative Fishery Research Unit, pers. comm.).

There is no commercial steelhead fishery in California today. Commercial salmon trollers cannot legally possess steelhead, and very few are taken incidently in the commercial salmon catch (Alan Baracco, DFG Senior Marine Biologist, pers. comm.). There is no ocean sport fishery for steelhead.

There is a well-established inland steelhead sport fishery in California. In 1991, there were an estimated 99,700 steelhead anglers (16 years and older) in California (Sylvia Cabrera, Project Leader, National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, USFWS, pers. comm.). This estimate is substantially less than the 190,900 California steelhead anglers estimated by the 1985 National Survey. These two estimates cannot be compared however, because different survey methodologies were used to generate them. The 1985 estimate is believed to be inflated, and the 1991 figure is more accurate (Sylvia Cabrera, pers. comm.).

The majority of angler effort is expended in the large river systems and smaller coastal streams north of San Francisco Bay and, to a lesser degree, in the Sacramento River system. There are a few rivers and streams south of San Francisco Bay that still support a steelhead sport fishery, but angling opportunities have become limited in recent years as a result of reduced access and low fish numbers. The steelhead fishery of southern California (south of San Luis Obispo) is almost nonexistent due to severe declines and extirpation of many of the runs. There are a few historical accounts of a steelhead fishery in the San Joaquin River system; at present it does not support a steelhead sport fishery.

Steelhead sport fishing is important not only for its recreational value, but also for the economic benefit that it provides. Meyer Resources Inc, (1988) conducted an analysis of the economic benefits that would result from increasing California's salmon and steelhead stocks. They estimated that doubling salmon and steelhead stocks would increase commercial and sport fishing business revenues by approximately 75 million dollars per year and the annual net income to businesses would be 30 million dollars (Table 2). Total benefit to the California economy was estimated to be approximately 147 million dollars per year.

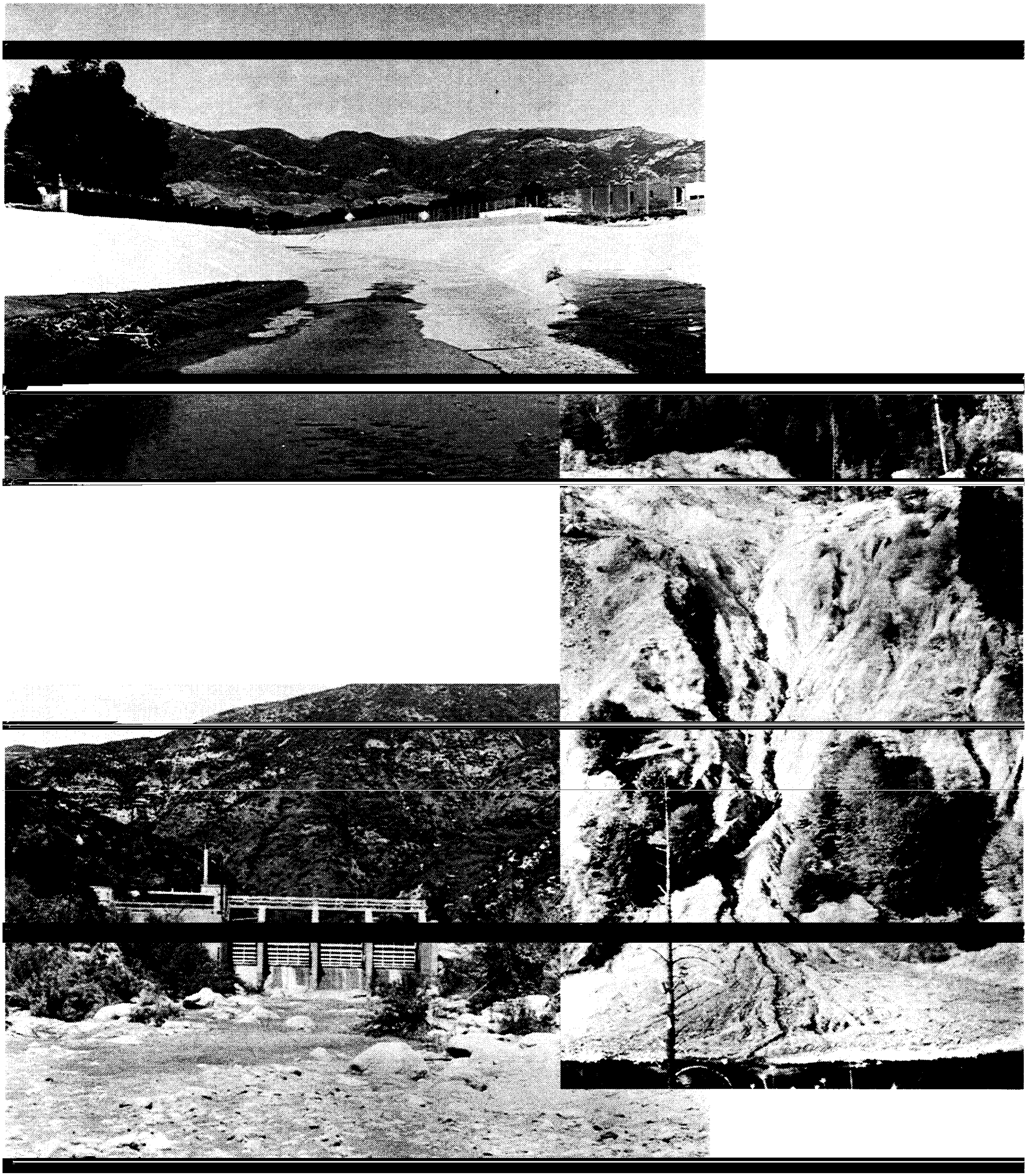
An estimated 37.5 million dollars per year from sport fishing revenues would result from doubling California's steelhead populations (Meyer Resources, Inc. 1988) (Table 2). In the Sacramento and Klamath river systems, steelhead account for over 20 million dollars annually, which is 16 percent of the total Salmonid commercial and sport fish revenues for these systems'. In the Klamath system alone, steelhead sport fishing provides 52 percent of the total Salmonid commercial and sport fishing revenues. Increasing steelhead sport catch in the Carmel and Ventura River systems to 2,000 and 1,000 adult fish, respectively, would generate economic benefits of 1.1 and 0.6 million dollars annually (Meyer Resources, Inc. 1988).

' Calculations are derived from data given in Meyer Resources, Inc. (1988) and are based on their estimates of stock size and catch rate.

Table 2. Estimated benefits of doubling California's salmon and steelhead populations. Modified from Meyer Resources, Inc. (1988).

River **System**	**Net Annual Economic Benefits (millions of dollars)**				
	Salmon and Steelhead				
				8.0	7.9
	0.05	1.1	0.05	1.1	100.0
Rivers	0.35				
Total Statewide Benefit:	**30.0**	**147.1**	**1.9**	**37.5**	**25.5**

PART II: STATUS



OVERVIEW

The *California Fish and Wildlife Plan* (CDFG 1965) estimated the total annual statewide spawning escapement of steelhead in the early 1960s to be 603,000[1]. An estimated 303,500 angler-days were spent fishing for steelhead per year, and an estimated 122,250 steelhead were landed annually.

Because of the difficulty in assessing steelhead populations, there are few good estimates of adult numbers and an accurate statewide population estimate is difficult to derive. Carcass surveys, a dependable method to estimate salmon spawning populations, are not very useful for assessing steelhead spawning populations because steelhead do not necessarily die after spawning and spawning typically occurs when stream flows are most affected by winter storms. Counts made at counting weirs and fishways can be difficult because adult steelhead tend to migrate on high, turbid flows when visual observation is difficult or impossible. Hatchery counts can be an indication of run size but should be used with caution because the entire hatchery escapement is not always counted in some years (Ron Ducey, DFG Hatchery Manager, pers. comm.). Despite the lack of accurate numbers, reliable indicators such as fishway counts, escapement estimates, population surveys, and angler surveys show that steelhead, like most other anadromous Salmonid stocks in California, are declining.

Light (1987) estimated the annual abundance of adult steelhead in California to be 275,000 adults. This is a rough estimate and is probably high (Eric Gerstung, DFG Associate Fishery Biologist, pers. comm.) but it provides a general view of the magnitude of steelhead abundance (Burgner et. al 1992). The California Advisory Committee on Salmon and Steelhead Trout (1988) estimated the statewide production of adult steelhead to be 240,000. Although this figure is similar to Light's estimate, the two are not readily comparable because of the imprecise nature of the data used to generate the estimates. They do, however, reflect a decline from the 603,000 adult steelhead estimated 23 years earlier in the *California Fish and Wildlife Plan.*

The lack of reliable and accurate population estimates for California steelhead does not conceal the ominous declining trend of this resource. Sport fishing catch rates are low nearly everywhere in the State. Fishway counts and population surveys where there are

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[1] Most of the estimates for steelhead in the *California Fish and Wildlife Plan* were derived by comparison with other better-studied streams and not by analysis of escapement, population, count, or catch data; hence these numbers may not be very accurate and should be used with caution.

several years of data show a tremendous decline. Entire runs, particularly on the south coast, have become extirpated within the last two decades.

A substantial amount of steelhead habitat has been lost or degraded, due primarily to decreased flows because of water diversions and groundwater extraction, blocked or hindered access to spawning and rearing areas by dams and other structures, unscreened or poorly screened diversions which entrain juvenile fish, and soil disturbances resulting from poor land use practices in the watersheds. Natural events, such as the recent drought, the 1964 flood, and adverse ocean conditions have probably played a role in the decline. The 1986-1992 drought has certainly exacerbated the problem, but most of the population declines began prior to the drought.

The decline of California's steelhead populations reflects the alarming trend of declining Salmonid populations coastwide. Nehlsen et al. (199 1) identified 2 14 Pacific Salmonid stocks at risk in California, Oregon, Idaho, and Washington, including 101 stocks that were judged to be at high risk of extinction or possibly already extinct. Coastwide (excluding British Columbia and Alaska), 75 steelhead stocks were identified as being at risk, 17 of which occur in California. They attribute the decline to habitat loss and damage, inadequate passage and flows, over-fishing, and interactions with exotic species. Cooper and Johnson (1992) also have identified a declining trend among steelhead populations coastwide from British Columbia to California.

This decline has prompted the Oregon Natural Resources Council et al. (1994) to petition the National Marine Fisheries Service (NMFS) to place steelhead populations in California, Oregon, Washington, and Idaho under the protection of the Endangered Species Act (ESA). NMFS is presently conducting a status review to determine which individual stocks (or groups of stocks) meet the criteria of "species" as defined under the ESA and if the status of these individual stocks warrant listing as threatened or endangered.

For purposes of this plan, steelhead populations are grouped into three management areas: North Coast (north of San Francisco Bay), Central Valley, and South Coast (south of San Francisco Bay). This management area designation does not necessarily reflect biological domains or infer stock relationships, but the areas do contain steelhead stocks with similar life histories and characteristics. Also, stocks within each area are subject to similar impacts, hence management objectives within each area will be similar. This section discusses the status of populations within each management area. Management objectives for steelhead within the three areas are discussed in Part III.

CENTRALVALLEY

DISTRIBUTION

Steelhead ranged throughout the tributaries and headwaters of the Sacramento and San Joaquin rivers prior to dam construction, water development, and watershed perturbations of the 19th and 20th centuries. Present steelhead distribution in the Central Valley drainages has been greatly reduced (Figs. 2 and 5).

The steelhead sport fishery in the Sacramento River below Redding developed largely after Shasta Dam was built, either because the changed flow and temperature regimes resulted in better conditions and hence more fish or the controlled flows simply made steelhead more available to anglers (Skinner 1962). Steelhead runs also occurred historically in west side streams such as Stoney and Thomes creeks (Murphy 1946).

There is little historical documentation regarding steelhead distribution in the San Joaquin River system. Sixty-six and five steelhead were counted at Dennet Dam on the Tuolumne River near Modesto in 1940 and 1942, respectively (CDFG unpublished data). The installation of diversion dams on the major tributaries in the late 19th and early 20th centuries, such as La Grange Dam on the Tuolumne River and Exchequer Dam on the Merced River, probably caused a decline in steelhead numbers prior to the early fish surveys that took place in the 1930's and 40's. The absence of an established steelhead sport fishery in the San Joaquin River probably explains the paucity of information regarding steelhead in this drainage. It can be assumed, however, based on known chinook salmon (0. *tshawytscha)* distributions in this drainage, that steelhead were present in the San Joaquin River and tributaries from at least the San Joaquin River headwaters northward.

STATUS

Hallock et al. (1961) estimated the average annual steelhead run size in the Sacramento River system above the mouth of the Feather River for a six-year period beginning in 1953 to be 20,540 fish. The *California Fish and Wildlife Plan* estimated an annual run size of about 30,000 steelhead for this same area, and a total annual run size of 40,000 adults for the entire Central Valley (including San Francisco Bay tributaries).

Although an accurate estimate is not available, the present annual run size for the total system, based on Red Bluff Diversion Dam (RBDD) counts, hatchery counts, and past

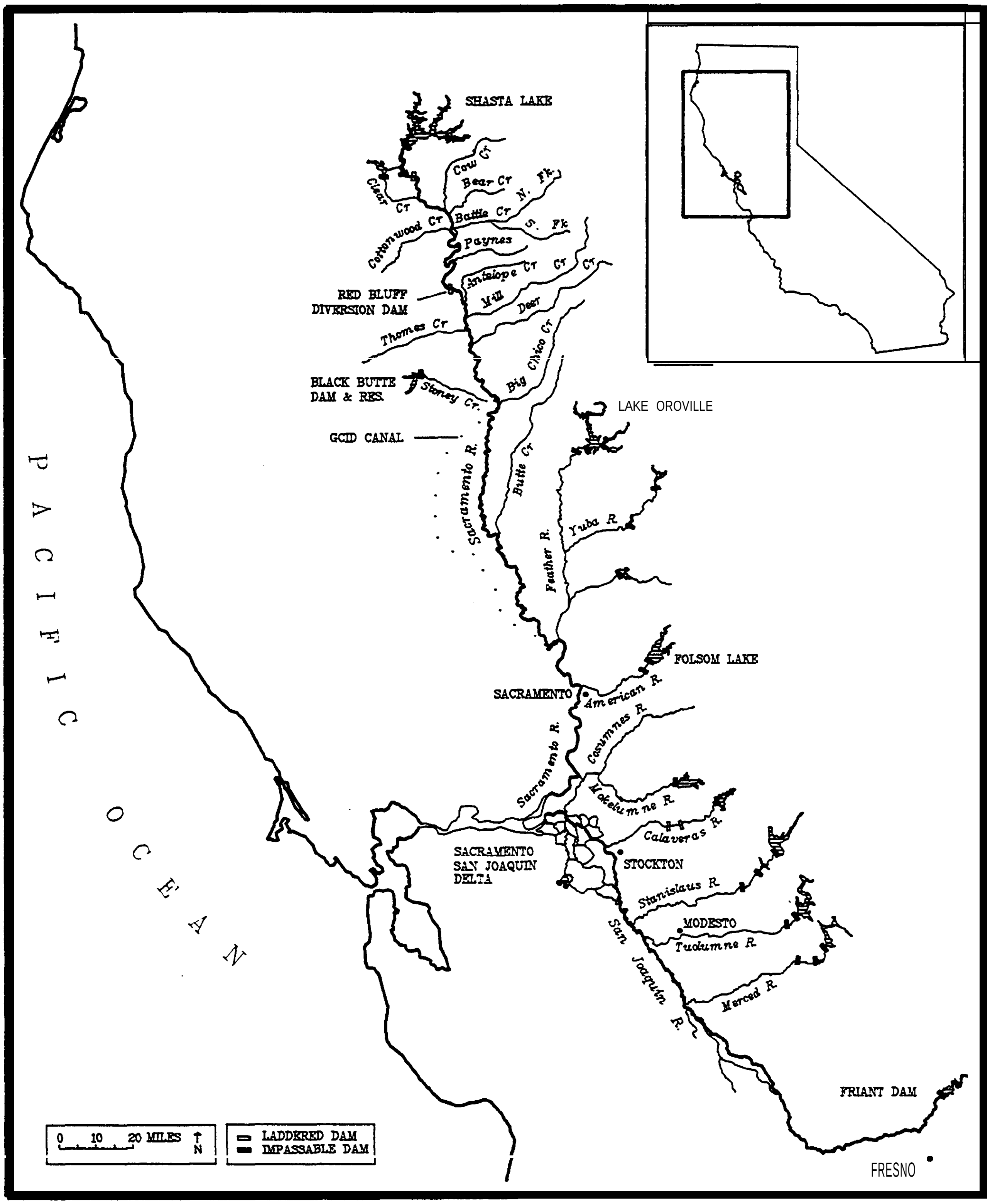

Figure 5. Rivers and streams of the Central Valley.

natural spawning escapement estimates for tributaries, is probably less than 10,000 adult fish. More reliable indicators of the magnitude of the decline of Central Valley hatchery and wild stocks are the trends reflected in the RBDD and hatchery counts (Figs. 6 and 7). Steelhead counts at the RBDD have declined from an average annual count of 11,187 adults for the ten-year period beginning in 1967, to 2,202 adults annually in the 1990's. Recent counts at Coleman, Feather River, and Nimbus hatcheries are also well below the average for these hatcheries (Fig. 7).

The Feather, Yuba, and American rivers are major tributaries to the lower Sacramento River and at one time supported large populations of steelhead. Today, the historical headwater spawning and rearing habitats of these rivers are inaccessible due to the installation of large dams. Feather River Hatchery on the Feather River and Nimbus Salmon and Steelhead Hatchery on the American River each produce 400,000 steelhead yearlings annually to mitigate for Oroville and Folsom dams, respectively.

The hatchery maintained runs have also declined. The estimated steelhead run size in the American River in 1971-72 and 1973-74 was 19,583 and 12,274, respectively (Staley 1976). Staley (1976) also estimated the steelhead harvest rate for the American River to be 27% for these two seasons. Assuming the harvest rate is the same, run sizes of 305, 1,462, and 255 are estimated to have occurred for the 90/91 through 92/93 seasons, respectively, based on the escapement into the hatchery. These estimates do not include steelhead adults that are less than 20 inches in length (Staley considered all rainbow trout greater than 14 inches to be steelhead; Nimbus counts include only rainbow trout greater than 20 inches), however, few steelhead less than 20 inches are observed at the hatchery (Ron Ducey, DFG Hatchery Manager, pers. comm.). Correcting for this bias, or if there is currently a greater

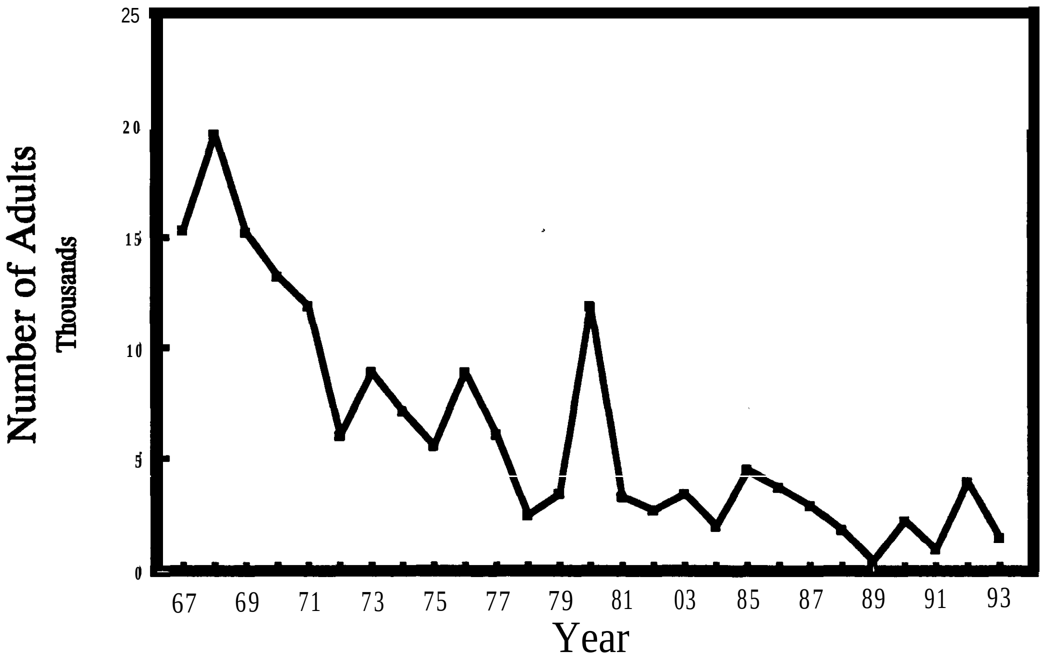

Figure 6. Adjusted adult steelhead counts at Red Bluff Diversion Dam on the Sacramento River, 1967- 1993.

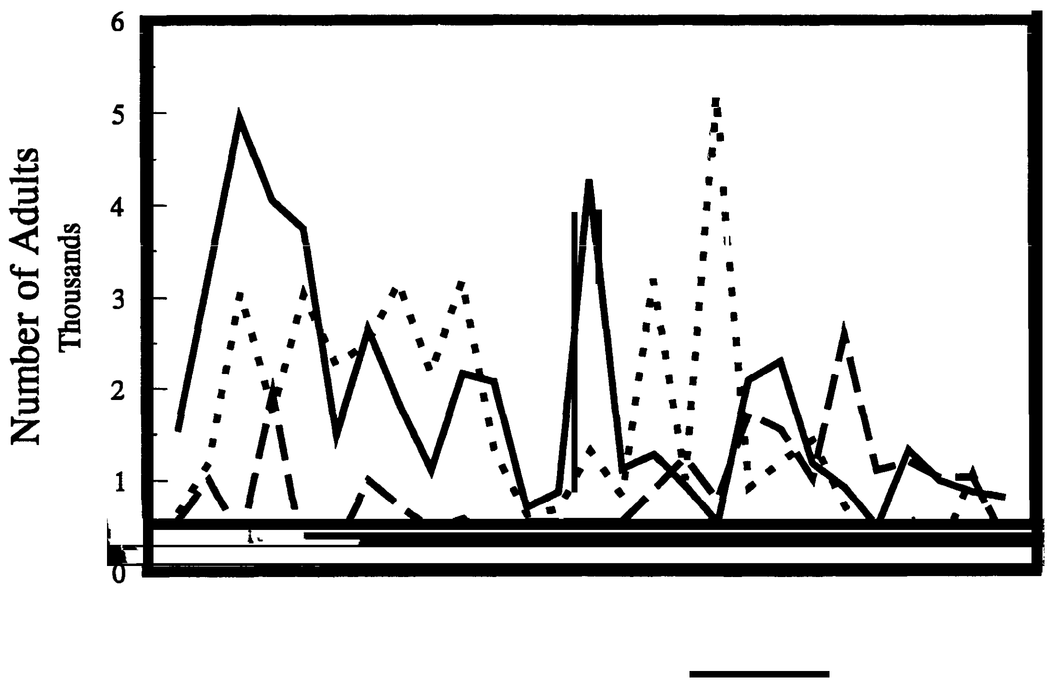

Figure 7.

19,6 15 (1968). They derived these figures by subtracting the number entering Coleman Hatchery (hatchery escapement) from the RBDD counts, assuming that the difference represents the naturally spawning component of the total run. This method does not, however, take into account harvest and natural mortality.

The average estimated harvest rate on adult steelhead above RBDD for the three year period 1991/92 through 1993/94 is 16% (DFG unpublished data). Applying this rate to the fish counted at RBDD yields significantly lower estimates of natural spawning in the Sacramento River system above RBDD, assuming that there is no difference in harvest rate of hatchery and naturally spawning fish. Natural spawning escapement estimates for the period 1967 to 1991, corrected for harvest, averaged 3,465 and ranged from 0 (1989 and 1991) to 13,248 (1968) (Table 5). These estimates should be considered maximum estimates, however, because mortality from natural causes is not taken into account.

Presently, approximately 10 % to 30 % of the adults returning to spawn in the Sacramento system are of natural origin (Frank Fisher, DFG Associate Fishery Biologist, pers. comm.). Hallock et al. (1961) reported that the composition of naturally produced steelhead in the population estimates for the 1953-54 through 1958-59 seasons ranged from 82 % to 97 % and averaged 88 % . Clearly, the decline of natural reproducing populations has been more precipitous than that of the hatchery stocks.

Wild stocks in the Sacramento system are mostly confined to upper Sacramento River tributaries such as Antelope, Deer, and Mill creeks and the Yuba River. Remnant populations may also exist in. Big Chico and Butte creeks. Few wild steelhead are produced in the Feather and American rivers mainly because of inadequate conditions for juvenile rearing. The Yuba River still has natural production and is managed by DFG as a naturally sustained population (CDFG 1991a). The run size in the Yuba River in 1984 was estimated to be about 2,000 steelhead (CDFG 1984). Current status of this population is unknown, although it appears to be stable and continues to support a steelhead fishery. The Yuba River is essentially the only wild steelhead fishery remaining in the Central Valley.

The wild stocks in Mill, Deer and Antelope creeks, and other upper Sacramento River tributaries may be native or mostly native Sacramento River steelhead (Frank Fisher, DFG Associate Fishery Biologist, pers. comm.); however, these populations are nearly extirpated. Annual counts made at Clough Dam on Mill Creek from 1953 to 1963 ranged from **417** to 2,269 adults. In 1964, 1,006 adult steelhead were counted at Vina Dam on Deer Creek.

In 1993, fish counters were installed at Clough and Vina dams (Harvey, 1995). The counters, although not operated continuously due to malfunction and high flows, were in place from mid-October, 1993 to mid-January, 1994. Historically, approximately 60 % of

Table 5. Upper Sacramento River adult steelhead harvest and population estimates.

Year	RBDD Counts	Estimated Harvest	Coleman Escapement	Natural Escapement	Natural Run Size
1967	15,312	2,450	1,532	11,330	13,488
1968	19,615	3,138	3,229	13,248	15,771
1969	15,222	2,436	4,939	7,847	9,342
1970	13,240	2,118	4,406	7,706	8,423
1971	11,887	1,902	3,742	6,543	7,432
1972	6,041	967	1,486	3,588	4,272
1973	8,921	1,427	2,645	4,849	5,772
1974	7,150	1,144	1,834	4,172	4,967
1975	5,579	893	1,099	3,587	4,271
1976	8,902	1,424	2,162	5,316	6,328
1977	6,099	976	2,069	3,054	3,636
1978	2,527	404	697	1,426	1,697
1979	3,499	560	865	2,074	2,469
1980	11,887	1,902	4,264	5,721	6,811
1981	3,363	538	1,118	1,707	2,032
1982	2,757	441	1,275	1,041	1,239
1983	3,486	558	938	1,990	2,369
1984	2,036	326	529	1,181	1,406
1985	4,489	718	2,084	1,687	2,008
1986	3,769	603	2,229	867	1,032
1987	2,963	474	1,176	1,313	1,563
1988	1,872	300	915	657	783
1989	470	75	492	0	0
1990	2,272	364	1,319	589	702
1991	991	159	991	0	0
1992	4,032	645	870	2,517	2,996
1993	1,511	242	805	464	553
Avg.	6,292	1,007	1,830	3,465	4,125

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1990	2,272	364	1,319	589	702
1991	991	159	991	0	0
1992	4,032	645	870	2,517	2,996
1993	1,511	242	805	464	553
Avg.	6,292	1,007	1,830	3,465	4,125

the run passed the fishways on these dams during this time period (Hallock 1989). Fourteen steelhead were visually counted on Mill Creek, which yields a total estimate of 28 adult steelhead passing Clough Dam. On Deer Creek, zero steelhead were observed during this same time period. Because the counters were not operated continuously, these estimates should be considered minimum estimates. It is clear, however, that there has been a tremendous decline of steelhead in these two streams.

Impacts to natural and hatchery-maintained stocks in the Sacramento River system are due mostly to water development: inadequate instream flows caused by excessive water diversions for irrigation; rapid flow fluctuations due to water conveyance needs; lack of cold water releases from reservoirs; loss of spawning and rearing habitat due to dams which block access; and entrainment of juveniles into unscreened or poorly screened diversions. The operations of the Federal Central Valley Project and the State Water Project, particularly the pumps in the south delta, may have a detrimental effect on steelhead smolts in the Sacramento-San Joaquin delta/estuary.

STOCKS

Steelhead stocks in the Central Valley are all winter steelhead. Hallock et al. (196 1) found that adult steelhead migrate into the upper Sacramento River during most months of the year. They begin moving through the main stem in July, peak near the end of September, and continue migrating through February or March (Bailey 1954; Hallock et al. 1961). An analysis of counts made at RBDD from 1969 through 1982 follow the same time pattern, although some fish were counted during April and May (Hallock 1989). Bailey (1954) also noted a few steelhead trapped in June at Fremont Weir on the main stem Sacramento (about 28 miles upstream from the City of Sacramento). Central Valley steelhead spawn mainly from January through March, but spawning can begin as early as the latter part of December and can extend through April (Hallock et al. 1961).

A compilation of weekly counts made at Clough Dam on Mill Creek from 1953-54 through 1962-63 also shows a similar migration pattern (Hallock 1989), with the peak of the run arriving in mid-November. There is a second peak in February, however, which is not reflected in the counts made in the main stem (Bailey 1954; Hallock et al. 1961) nor the counts at RBDD (Hallock 1989).

There are indications in early, pre-dam fish counts that summer steelhead may have been present in the Sacramento River system. Needham et al. (1941) reported 36 steelhead passing through a fishway near Redding from April 17 through September 1. Counts made at the Old Folsom Dam fishway from 1943 through 1947 showed that the bulk of the run migrated through the American River in May, June, and July (Anonymous 1953). There are no summer steelhead in the Sacramento River system today. Because of their need to over-summer in deep pools in the headwaters, they would have been eliminated with the commencement of the large-scale dam construction period of the 1940's, 50's and 60's.

There is no information on run timing or life history of the San Joaquin River stocks. Sixty-six steelhead observed from October 1 through November 30 at Dennet Dam on the Tuolumne River in 1940 (DFG unpublished data) indicate that winter steelhead were present. It is not known, however, if counts were made after December 2, the last date noted on the count report form. The presence of spring-run chinook salmon in this system indicates that suitable over-summering habitat and other conditions were available to support a summer steelhead population.

Today, the hatchery runs in the Sacramento River system are probably a highly introgressed mixture of many exotic stocks introduced in the early days of the hatcheries. Beginning in 1962, steelhead eggs were imported into Nimbus Hatchery from the Eel, Mad, upper Sacramento, and Russian rivers and from the Washougal and Siletz rivers in Washington and Oregon, respectively (McEwan and Nelson 199 1). Egg importation has also occurred at other Central Valley hatcheries.

PART III: MANAGEMENT PLAN

A fishery management plan should address the three components of a fishery: the fish population, its habitat, and the human user. In situations where a fish population is declining primarily because of habitat degradation and loss, most attention should be focused on habitat restoration and alleviation of factors leading to decline of habitat. This is the case with steelhead in California. For this reason, this management plan focuses primarily on habitat restoration.

A day's catch of steelhead from the Ventura River, 1946. Photo courtesy of Mark H. Capelli

HABITAT RESTORATION

WATERSHED INTEGRITY

River systems are inextricably linked to the processes which shape and maintain their watersheds. Salmonid habitats within river systems are products of the geology, soils, topography, vegetation, climate, and hydrology of a watershed (Meehan 1991). Natural events and land-use activities in a watershed can dramatically affect a river system and its biota.

The catastrophic 1964 north coast flood is often cited as an example of a natural event that drastically altered the structure, function, and aquatic biota of a major river system, the Eel River. In reality, it is a good example of how natural forces and poor land-use practices can combine to cause severe impacts. The 1964 storm provided the energy to mobilize slopes and soils destabilized by decades of poor land-use practices. The massive amounts of sediments transported down-slope and downriver have aggraded the stream channel, filled-in pools, and created other conditions from which the aquatic habitats of the Eel River have not yet recovered.

Though not as impressive in scale as major flooding events or other natural processes, land-use activities that result in incremental degradation of river system environments are much more prevalent and have the potential for greater cumulative impacts. Historically, activities associated with logging, road construction, urban development, mining, livestock grazing, and recreation have reduced the quality of fish habitat by changing streambank and channel morphology, altering water temperature, degrading water quality, and blocking access to spawning areas. These activities have also caused a decrease in water retention of the watershed, which results in increased wet season flows and diminished dry season flows; and an increase in sediment loads, which results in scour, smothered spawning gravels, in-fill of pools, and aggradation of streambeds. In some instances, changes in the watershed can alter habitat conditions to favor introduced fish species to the detriment of native ones. Concern over the effects of land-use activities (principally timber harvest and livestock grazing) on Salmonid habitats have been raised since the late 1800s and attempts to effectively mitigate the damage began in the early 1900s. Mitigation efforts were significantly accelerated in the 1970s.

- **Watershed restoration and protection must be a focal point of DFG's efforts to restore steelhead populations.**
  Watershed restoration and protection are basic prerequisites for restoring and maintaining naturally produced steelhead and other anadromous fish.

Establishment of conditions, constraints, and practices which maintain watershed integrity, and restoration of problem areas which continue to degrade aquatic habitats, are of the utmost importance to restoring steelhead populations.

It is beyond the scope of this management plan to address specific watershed restoration activities that will restore steelhead populations and habitat. This will be left to basin or ecosystem plans. However, several general concepts and practices that will lessen the harmful effects from various land-use activities are discussed below.

Timber Harvest

Timber harvest and silviculture are major land-use activities that have severely degraded steelhead and other anadromous Salmonid habitats. While current practices have improved, damage sometimes still occurs. Logging in riparian areas can have deleterious effects on Salmonid habitats: removal of large trees can lead to bank instability, loss of instream cover, and a decrease in organic inputs, recruitment trees, and shading. Construction of roads and stream crossings within these areas can cause severe bank and soil disturbances and downstream sedimentation.

Under the current California Board of Forestry Forest Practice Rules, logging operations can reduce the overstory shading level by 50% in stream-side protection zones near Class 1 (fish bearing) streams. In some circumstances, more shade is necessary to maintain suitable temperatures and microclimates (Jim Steele, DFG Environmental Services Supervisor, pers. comm.) .

Roads and skid trails constructed for timber harvest operations can be greater contributors of sediment to a stream than falling, skidding, and yarding combined (Furniss et al. 199 1). Destabilized hillsides, road fill failures, erosion from roadbed surfaces, accelerated scour at culvert outlets, stream crossing failures, and other problems can become dramatic and persistent sediment inputs to a stream.

Recommendations

- **Forest Practice Rules governing riparian zone protection on private timber lands should be implemented consistently so that the integrity of streams and associated riparian areas is maintained. Bank stability and adequate**

amounts of large woody debris, instream cover, and shade trees should be retained.

- **Harvest of select trees in the riparian zone should be allowed only if habitat values (such as adequate large woody debris, cover, canopy, and water temperatures) and integrity of the stream can be maintained. The rules governing stream buffer zone widths should be determined on a site-by-site basis to provide protection for steelhead streams from timber harvest related activities. No new road construction in riparian zones should be allowed, except as needed to cross a stream.**

F **Greater protection should be given to headwater areas.**
Streams in these areas provide important spawning and rearing habitat for steelhead. Also, sediment produced in these areas can negatively affect all downstream habitats.

- **Ephemeral streams should be protected from timber harvest impacts.**
These streams provide seasonal habitat and are important for maintaining adequate water temperatures, food, and large woody debris recruitment into permanent streams. Also, sediment generated from activity in these water courses will eventually be deposited in spawning and rearing habitat of perennial streams.

- **"Light touch" timber harvest methods should be used wherever necessary to reduce ground disturbance.**
Skidding of fallen timber and yarding operations can increase soil compaction and exposure. This reduces the infiltration capacity of some soils, resulting in less water retention and increased runoff. Tractor skidding generally causes the greatest amount of soil disturbance; helicopter log removal the least. However, the amount of disturbance and degradation is highly dependent on the type of soil, equipment used, operator experience, and especially topography. For example, high-lead cable yarding (one end of the log is suspended, the other end is dragged) can cause greater soil disturbance on steep slopes than tractor yarding on flat terrain (Chamberlin et al. 1991).

- **Unnecessary roads should be decommissioned, which entails removing the road fii and all culverts and restoring the natural slope. Road culverts should be properly sized and located to prevent culvert failure and road wash out.**

- **Index streams that are considered typical or representative of a specific area should be established and routinely monitored to assess the effects of timber harvest practices.**
  Post-logging aquatic habitat condition is the best indicator of adequate timber harvest practices (Chamberlin et al. 1991), yet very few thorough, long-term, documented assessments of habitat condition occur after timber is harvested.

The Federal Government has recently initiated efforts to resolve the impasse concerning timber harvest on Federal lands in California and the Pacific Northwest due to conflicts with Endangered Species Act protections for the northern spotted owl (*Strix occidentalis* required before any management activities can take place. No roads can be constructed in inventoried roadless areas, and it is recommended that existing road mileage within Key Watersheds be reduced.

Table 6 shows important summer steelhead streams within watersheds proposed for Key Watershed Designation. Implementation of the Aquatic Conservation Strategy and the establishment of Key Watersheds will provide major benefits to stream systems used by 96% of California's summer steelhead populations, 55 % of naturally-produced spring-run chinook salmon, and a majority of sea-run cutthroat trout (0. clarki) (Calif. Dept. of Forestry and Fire Protection 1993).

Federal land management agencies have recognized the need to protect and restore aquatic habitat to stem the decline of anadromous fishes due to habitat degradation from land-use activities. They have established an ecosystem-based strategy to arrest the degradation and begin restoration of aquatic habitat and riparian areas in fish producing watersheds. This strategy, termed PACFISH, is intended to improve aquatic habitat conditions on U.S. Forest Service (USFS) and Bureau of Land Management (BLM) administered lands outside the range of the northern spotted owl. In California, this includes Lassen and Los Padres National Forests and BLM's Bakersfield and Ukiah Districts.

Table 6. Important summer steelhead streams benefitting from Key Watershed designation.

Klamath River Tributaries	Eel River Tributaries
Red Cap Cr.	M.F. Eel R.
Bluff Cr.	
Elk Cr.	Smith River Tributaries
Dillon Cr.	
Clear Cr.	N.F. Smith R.
Salmon Cr.	M.F. Smith R.
Wooley Cr.	S.F. Smith R.
Trinitv River Tributaries	
N.F. Trinity R.	
S.F. Trinity R.	
New R.	
Canyon Cr.	

PACFISH focuses on the maintenance and restoration of entire watersheds; specifically, those features required for healthy aquatic ecosystems: cool water temperatures, adequate amounts of woody debris, reduced sedimentation, increased streambank stability, and appropriate pool habitat attributes. Components of the strategy include: identifying and analyzing Key Watersheds; determining goals, site-specific riparian management objectives, and associated standards and guidelines; creating riparian habitat conservation areas; and restoring watersheds.

USFS and BLM are developing geographic-specific Environmental Impact Statements (EIS) and analyzing long-term management strategies. The EIS's may result in amendments to BLM land-use plans and USFS forest plans to provide greater protection and restoration of anadromous fish habitats in fish-producing watersheds. While the EIS's are being developed, USFS and BLM are implementing an interim policy so that restoration can begin immediately.

- **The implementation of the Aquatic Conservation Strategy and the establishment of Key Watersheds will be a major step in protecting and restoring steelhead stocks that are declining due to watershed-related impacts.**

Grazing

Livestock grazing is another major land-use activity that can have detrimental effects on streams. The general consensus among researchers is that improper or excessive livestock grazing degrades riparian and aquatic habitats, resulting in decreased production of salmonids (Platts 1991). Effects can range from changing or reducing riparian vegetation to eliminating it altogether. Impacts to the stream can result through physical trampling of the streambank, channel widening and aggradation, and downcutting, which lowers the surrounding water table. Overgrazing upland areas can cause excessive erosion and increased sediment inputs to the stream, which can have detrimental effects on downstream areas.

The Clean Water Act of 1977 requires states to identify nonpoint sources of water pollution, including those from livestock grazing, and develop Best Management Practices to restore and maintain water quality for domestic use, agricultural use, and fish and wildlife. The Clean Water Act is only one of many laws that requires change and improvement in the way that watersheds and riparian areas are grazed.

There are several grazing management strategies designed to improve and restore rangelands and protect riparian and aquatic habitats. These strategies range from total exclusion of livestock from certain areas, to limiting the season, duration, or intensity of grazing.

Recommendations

- **Grazing management plans developed for a specific area should: limit grazing intensity so that adequate plant vigor, regrowth, and energy storage is maintained; ensure that there is sufficient vegetation during periods of high flows to protect streambanks, dissipate energy, and trap sediments; and limit timing of grazing to prevent damage to streambanks when they are most vulnerable to trampling.**

- **On public lands, cattle should be excluded from riparian areas where they are inducing damage through erosion, trampling, or water quality impairment.**

- **DFG should continue to support reducing the permit tenure for livestock operators on public lands to five years or less.**
  This would facilitate recovery of degraded range and riparian lands by excluding from renewal operators that demonstrate harmful practices (CDFG 1994b).

- **Federal land managers need to fully implement and enforce existing laws, policies, and requirements to protect public lands from harmful grazing practices.**
  The success of new grazing strategies that are developed and implemented to protect and restore public land will depend upon proper enforcement.

- **DFG should continue to pursue cooperative programs with landowners to improve conditions in riparian corridors on private lands.**

[redacted]

STREAM RESTORATION

Instream Flows

There are many streams and rivers in California where water has been over-appropriated. This is a major cause for the current decline of steelhead (and other aquatic species in general) in California (California Advisory Committee on Salmon and Steelhead Trout 1988; CDFG 1990; CDFG 1992a). Flow depletions are not as extreme during periods of ample precipitation, but the recent six-year drought has demonstrated that there is virtually no water to spare for instream uses in many areas of the State.

There are several state and federal laws which provide for the protection of streamflows:

> Fish and Game Code 5937: Mandates that sufficient water be released below any dam to keep fish that exist below the dam in good condition.
>
> Fish and Game Code 1601 and 1603: States that persons, public agencies, utilities, etc. must notify DFG of plans to substantially divert or obstruct the natural flow or substantially change the bed, channel, or bank of rivers, streams, and lakes. DFG will submit proposals to reduce or mitigate impacts from the proposed project.
>
> Fish and Game Code 6900 et. seq.: Declares that it is a policy of the State to significantly increase the natural production of salmon and steelhead trout and that existing natural salmon and steelhead habitat is not diminished further without offsetting impacts of the lost habitat.
>
> California Water Code 1243: Declares that the use of water for preservation and enhancement of fish and wildlife resources is a beneficial use. Requires the State Water Resources Control Board (SWRCB) to notify DFG of any application for permit to appropriate water.
>
> California Water Code 1707: A new law passed by the California Legislature and signed by the Governor in 1991, it authorizes a water right owner to petition the SWRCB for a change for purposes of preserving or enhancing wetlands, habitat, fish, and wildlife. It authorizes the SWRCB to approve the petition, regardless of whether the proposed use involves a diversion of water. In other words, the law allows for an <u>existing</u> water right to be left in the stream to

benefit fish and wildlife, instead of being diverted for consumptive, or out-of-stream uses.

Public Trust Doctrine: Under this doctrine, title to tidelands and lands under navigable water are held in trust by the State for the benefit of the public. Acquired rights in navigable streams, lakes, and tidelands are subject to the trust and assert no vested right in a manner harmful to the public trust. The Public Trust Doctrine requires the SWRCB to "balance" the potential value of a proposed or existing diversion with the impact on the trust resources. Fish and wildlife are public trust resources in the custodial care of DFG.

California Wild and Scenic Rivers Act: Declares that water is generally not available for appropriation by diversion from, or storage in, a designated Wild and Scenic River, unless approved by an initiative of the voters or a two-thirds vote of the California Legislature.

Fish and Game Commission Water Policy: Declares that it is a policy of the FGC that the quantity and quality of the waters of the State should be apportioned and maintained to produce and sustain the maximum numbers of fish and wildlife. Requires that DFG review and comment on proposed water development projects and applications for use; recommends and seeks adoption of proposals necessary or appropriate for the protection and enhancement of fish and wildlife and their habitats; opposes the issuance of permits for, or authorization of, water projects which do not adequately prevent or compensate for damage to fish and wildlife.

Article 10, Section 2 of the State Constitution declares that "water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented.. . . ". According to the State of California Water Code, the use of water for preservation and enhancement of fish and wildlife is a beneficial use. An appropriative water right cannot be obtained for this purpose, however, because water left in a stream is not controlled or diverted. In order for water to be appropriated, it must be controlled or diverted.

DFG is automatically notified when an application to appropriate water is submitted to the SWRCB. If it is the opinion of DFG that the appropriation may harm fish populations, DFG can protest the water right application and present terms for the dismissal of the protest. To protect steelhead resources, DFG must determine if steelhead occur, or historically occurred, in the affected reach and what flows are necessary to maintain steelhead populations. DFG can require the applicant to obtain this information.

Theoretically, the burden of proof that fish and wildlife resources will not be impacted by the appropriation is on the applicant. A major problem with this procedure, as with environmental document review in general, is that DFG does not have adequate personnel to review all water right applications to determine if there will be impacts (Cindy Chadwick, DFG Environmental Specialist, pers. comm.).

It is more difficult to obtain adequate releases from an existing water project than it is to obtain protective terms for a proposed appropriation. Essentially, the burden of proof to show that fish and wildlife are being impacted by an existing project is on DFG. If evidence obtained from population surveys, instream flow studies, water quality monitoring, etc. show that fish populations are being adversely affected from inadequate flow releases, then DFG can file a complaint with the SWRCB.

- **DFG needs a more effective program with adequate staffing to review water rights and environmental documents, determine instream flow needs for specific streams, and pursue obtaining the necessary streamflows through regulatory and legal means.**
  A major problem with securing adequate flows for steelhead (and fish and wildlife in general) through the water rights process is that DFG is not adequately staffed to review all significant water rights applications and existing projects, determine if there will be, or are, adverse effects, and recommend conditions that will alleviate these effects.

The aforementioned laws and provisions notwithstanding, protection of instream flows is frequently inadequate. The Klamath River below Iron Gate Dam, the Sacramento River below Shasta Dam, the American River below Folsom Dam, the San Joaquin River below Friant Dam, the Santa Ynez River below Lake Cachuma, and the Ventura River below Casitas Dam are a few examples of former and present steelhead waters where severe environmental problems have resulted because of insufficient releases from upstream reservoirs. Although there have been several favorable court decisions affirming the protection of fish and wildlife under the Public Trust Doctrine, those resources held in trust in many areas of the State, such as the Sacramento-San Joaquin Delta/Estuary, continue to decline.

Recommendations

- **As a trustee agency, DFG should make the greatest possible effort to protect and enhance fish and wildlife public trust resources through enforcement of applicable regulations.**
  In many areas, the best solution to the problem of declining populations of steelhead is an aggressive enforcement of Fish and Game codes and other laws designed to protect instream flows and spawning habitat. The greatest protection for steelhead habitat can be achieved by maintaining and protecting adequate streamflows.

- **DFG should seek to augment instream flows through acquisition of riparian lands with water rights.**

Instream Habitat

Adverse watershed effects from logging, grazing, road building, improper construction practices, and hydraulic mining have historically contributed greatly to instream habitat degradation and continue to do so. In addition, impacts to instream habitat from gravel mining, dredging, flood control, and bank protection projects are a major cause of current habitat loss and degradation. Natural events, such as floods, droughts, and forest fires, can also contribute to habitat degradation, though not as great in scope as human-induced impacts. Also, there are many areas in the state where artificial barriers have eliminated access to historic spawning and rearing areas.

- **Maintaining healthy watersheds and sufficient flows must be our highest priority.**
  Site specific habitat restoration projects to remedy these problems can be myopic and early attempts at habitat restoration projects in the West met mostly with failure (Calhoun 1966; Reeves et al. 199 1). Nevertheless, restoration projects to correct past and ongoing localized environmental perturbations are a necessary and valuable component of the restoration of a fishery, if they are incorporated into overall management and restoration objectives. However, habitat restoration is no substitute for habitat protection: the best remedy for habitat degradation is to avoid it in the first place.

Recommendations

- **Restoration priority should be given to those projects that identify and correct problems that are most limiting to the target population.**
  All habitat restoration project planning must recognize that wild fish production is controlled by discrete, limiting factors. During the planning phase of any project, those aspects of habitat that are most limiting to a particular population must be identified. For example, little benefit to a natural steelhead population can be obtained by increasing spawning success through gravel augmentation if inadequate summer flows limit rearing capacity for juveniles.

- **Habitat improvement projects should be focused on the many areas throughout the State where steelhead habitat is severely degraded and restoration work is sorely needed.**
  Habitat restoration projects that attempt to 1) correct problems created by watershed damage or 2) restore access to historic habitats through barrier modification or removal should receive the highest priority for funding. Instream habitat improvement projects that do not address the underlying cause of instream habitat damage or those that are for the purposes of enhancing populations in healthy streams or extending range beyond existing natural barriers will be given a lower priority. Range extension for purposes of mitigation for damaged habitat is not an adequate substitute for rehabilitating damaged habitat.

- **Evaluation should be an integral part of all restoration or enhancement project designs.**
  There is a scarcity of written documentation of past projects done throughout the western United States, and many have not been evaluated at all (Reeves et al. 1991). Evaluations are valuable and necessary for improving the chances of success of future projects and for maintaining a continuing body of knowledge about techniques and applications. DFG's Inland Fisheries Division has established a position whose function will be to evaluate restoration projects that are funded through the Fishery Restoration Program.

Policies, applications, and techniques for habitat restoration of steelhead streams and other anadromous Salmonid streams are treated extensively in DFG's California Salmonid Stream Habitat Restoration Manual (Flosi and Reynolds 1994).

Mining

Current suction dredge mining regulations provide adequate protection for most steelhead spawning and rearing streams throughout the state. However, they may not be adequate to protect summer steelhead populations in several small Klamath River tributaries, such as Indian, Red Cap, Bluff, and Elk creeks. Dredging during the open season (July 1 through September 30) could be detrimental to adults that over-summer in these streams. Additional studies are needed to determine if impacts to summer steelhead populations are occurring.

The current regulations do not adequately protect southern steelhead populations, especially in that part of their range where populations are the most endangered. Coastal streams in Santa Barbara, Ventura, and Los Angeles counties are open year-round. All tributaries that are accessible to steelhead in the Santa Clara River system, (except a portion of Sespe Creek) are open year-round, as is the mainstem downstream of the Ventura-Los Angeles county line.

Recommendations

- **The regulations governing suction dredge mining are insufficient to protect some critical steelhead populations. Additional restrictions, including closures, may be necessary.**

- **If new regulations are adopted, they should be carefully monitored to determine if they are adequate to protect steelhead populations from suction dredge mining impacts.**

- **DFG should work closely with the mining industry to develop alternatives that do not cause adverse impacts to fiih.**

Gravel mining is a problem on north coast streams, particularly on those streams south of Humboldt Bay. Mining operations on the Eel, Garcia, Tenmile, Navarro, Gualala, and Russian rivers have the potential to significantly affect steelhead populations (Richard Macedo, DFG Environmental Specialist, pers. comm.). Site and timing of the operation and methods used to extract the gravel determine the magnitude of the impacts. Obviously, those operations that occur in steelhead spawning areas during spawning periods will have the greatest impact.

The major problems associated with gravel mining are:

<u>Changes in bank configuration and channel confinement</u> Removal of stream bank material can result in channel widening and a reduction in stream depth.

<u>Sediment inputs</u> Exposed sediments can be more rapidly mobilized and transported into the stream by floods or rain.

<u>Stranding</u> Mining operations often create pits and depressions that can strand juvenile fish when flows recede. This is a continual problem during periods of operation because stream bed restoration isn't done until the operation is closed.

<u>Reduction in gravel recruitment</u> Removal of gravel may reduce the amount available to replenish spawning gravels. This is particularly a problem in areas where dams have severely reduced gravel recruitment.

Fish and Game Code section 1505 is essential for the protection of steelhead spawning areas. This code authorizes DFG to manage, control, and protect important specified spawning areas on state lands as necessary to protect fish life. Twenty-four general spawning areas are specified, including portions of the Trinity, Eel, Van Duzen, Mad, Middle Fork and South Fork Smith, and Salmon rivers and all of the South Fork and Middle Fork Eel, Mattole, Noyo, Big, Gualala, and Garcia rivers. **The** code specifies that, in the event of conflict with other public agencies, DFG's opinion shall prevail except for actions taken by the State Water Resources Control Board (SWRCB) in establishing waste discharge requirements, and actions required for commerce, navigation, bridge crossings, water conservation or utilization, and flood protection.

Fish and Game Code 1505 states that until ownership of any land in the specified area is determined, DFG shall disapprove any stream alterations of salmon and steelhead spawning areas when such alterations could prove deleterious to fish life. However, the State Lands Commission may have jurisdiction over streambeds and side channels that are under state ownership.

<u>Recommendations</u>

- **DFG should adopt a uniform policy on gravel mining which should include the following:**

* **Measures to maintain channel integrity and reduce stranding of juveniles as standard conditions of stream bed alteration permits.**

* **Seasonal restrictions to protect spawning adults and eggs and fry in the gravel.**

* **Stream bed alteration permits with measures necessary to insure that public trust values are protected.**

► **DFG will work with county governments to develop county-wide gravel mining policies and land-use plans that are consistent with Fish and Game Code sections 1505, 1601, 1603, and 6900 (see page 70).**

Estuaries

It is well known that estuaries are very important rearing areas for juvenile salmonids (Shapovalov and Taft 1954; Smith 1990; Taylor 1992). Diversity and richness of habitat and food sources allow juveniles to attain a larger size before entry into the ocean, thereby increasing their chances for survival in the marine environment. Many of the fry of "ocean-type" chinook salmon, which begin emigration within weeks or a few months after emergence, are dependent upon estuary rearing to obtain smolt size (Healey 1991).

Steelhead populations in small coastal tributaries are more dependent upon the estuarine environment. This may be due to the limited rearing capacity in the headwaters of small stream systems and to the infrequent natural breaching of sandbars which form across the outlet of the estuaries or lagoons. Coots (1973) found that 34 % of the juvenile steelhead seined from the San Gregorio Creek lagoon from mid-June through August 1971 (which maintained its outlet to the ocean for most of this time) were sub-yearlings less than 100 mm in length. Marston (1992) found that 50 % of the juvenile steelhead inhabiting the Scott Creek lagoon in June and July 1992 were less than 90 mm in length and appeared to be pre-smolts. Smith (1990) analyzed scales from 27 adult steelhead collected from Pescadero Creek and found that 59% had reared in the lagoon. He also estimated that it would take eight stream miles to equal the numerical production of steelhead in the Pescadero lagoon.

Despite the need for permits required by DFG, the Coastal Commission, and the U.S. Army Corps of Engineers, artificial breaching of sandbars which form lagoons and estuaries regularly occurs (Smith 1990). Artificial breachings are done to alleviate flooding and salt water intrusion into ground water and surface diversions, and to provide beach access. In some instances, misguided anglers will breach sandbars on small streams to allow adults access to the stream. This can have a detrimental effect on survival of juvenile steelhead. Subjecting pre-smolt steelhead to sudden immersion in salt water and the loss of rearing habitat associated with draining a lagoon or estuary can significantly decrease survival.

Recommendations

- **DFG should continue to protect estuarine habitats by opposing non-emergency sandbar breachings so that habitat values are protected.** Conflicts between maintaining flood control and water quality and maintaining the lagoon/estuary systems for natural values will undoubtedly continue. Protection and alleviation of conflicts can best be achieved by acquiring ownership or easements for the most sensitive areas.

- **Methods to regulate lagoon levels that alleviate the need for artificial breaching should be developed and implemented.** Recent listing and proposed listing of estuary and stream dwelling species under the Endangered Species Act will undoubtedly escalate the conflicts concerning lagoon management. Methods to partially drain lagoons before they reach flood stage, without breaching the sand bar and substantially draining the lagoon, need to be developed and implemented so that flooding and salt water intrusion can be controlled.

Land Acquisition

Acquiring lands or easements to protect critical areas should be a high priority. Competing uses and increased development pressure that will inevitably come with the increasing human population can negate most protections that are currently in place. Court decisions, federal, state, and local government land-use planning, and other protections that protect important steelhead habitats can be overturned in future court decisions or future planning processes. Ownership of a critical area is the most secure strategy for protecting habitat.

- **DFG must identify critical steelhead habitats and begin steps necessary to acquire them. Priority should be given to acquisition of riparian lands that have water rights, stream reaches that support depressed native stocks, and estuaries.**

- **A high priority for use of “Proposition 70” money should be to acquire lands or easements to protect critical habitat.**
  A total of **$6** million for acquiring steelhead and wild trout habitat is potentially available from the California Wildlife, Coastal, and Park Land Conservation Fund of 1988 (“Proposition 70”) (see page 127).

NATURAL AND ARTIFICIAL PRODUCTION

VALUE OF NATIVE AND NATURAL STOCKS

During the early part of this century when West Coast anadromous fishery management was in its infancy, there was little knowledge and appreciation of the complexity of adaptations, the differing life histories, and the number of distinct stocks that comprised a Salmonid species. The need to maintain a diversity of stocks was not recognized. Maintenance of salmon and steelhead runs appeared easy: if a human activity caused the decline of a particular run, fish could be brought in from elsewhere or a hatchery could be built to maintain the run.

More recently, fishery managers, concerned anglers, and others have recognized the need to maintain the diversity and complexity of Salmonid stocks. Reasons for this can be grouped generally into ecological, genetic, and aesthetic categories and are described below.

Maintain Biodiversity and Ecosystem Integrity. California's wide diversity of landforms and wetlands sustains a wide range of ecosystems, which in turn supports a diversity of species. Genetic diversity allows for the wide variety of forms and behaviors found among individual species, which is essential to survival in sometimes harsh, changeable environments. These diverse biological resources not only contribute to the economic health of the State but also help to sustain a high quality of living for its citizens.

Individual populations, or stocks, of anadromous salmonids are adapted to the local environmental conditions of their natal stream systems, hence, a wide range of genetic variability exists between them. Loss of individual stocks will most likely lead to loss of genetic diversity and ultimately to changes in genetic composition of the species as a whole (Nehlsen et al. 1991), and a reduction in biodiversity. It is at the stock level that conservation and rehabilitation of Pacific salmonids should take place (Rich 1939).

Protection of individual stocks necessitates protection of the freshwater habitat on which they depend. This results in benefits to many species and to the ecosystem as a whole.

Maintain Genetic Diversity for Future Adaptations. Genes are the "blueprints" for a stock's adaptations to its natal freshwater environment. Alleles are different forms of a gene which can produce different effects on a trait. These alleles may or may not be expressed but they can persist. Maintaining a wide diversity of alleles provides the genetic basis by which the population can respond to fluctuating environmental conditions.

Environmental conditions at the periphery of a species' natural range are generally suboptimal, thus these stocks have adaptations that allow them to survive and reproduce in suboptimal or harsh environments (e.g. steelhead in southern California streams). The genetic basis of these adaptations are part of the species' gene pool and can be disseminated throughout the range by straying.

Re-establish Genetic Variability in Hatchery Stocks. A major concern among botanists and agricultural scientists is "genetic erosion", or loss of genetic variability, in strains of domesticated plants used by agriculture, and the need to maintain the wild strains from which the majority of the world's food plants are derived (Rhoades 1991). Domestication of plants and animals, including hatchery fish, tends to reduce genetic variability and vigor over time. Maintaining wild stocks insures that there will be a reservoir from which to reestablish genetic variability in hatchery stocks, and to insure a supply of "traits" to be manipulated in future domesticated strains.

Maintain Populations Best Suited to a Local Environment. A stock's fitness to its local environment is achieved through thousands of years of evolution. Replacing a stock that has been extirpated may be difficult because substitutes may not have the necessary characteristics to survive in their new environment. The genetic heritage of a stock cannot be readily recreated or maintained in a hatchery (Moyle 1991a).

Aesthetics. There is a perception among many anglers that wild fish are superior to hatchery fish in terms of physical characteristics, survivability, and wariness. This perception is also supported in the scientific literature (Reisenbichler and McIntyre 1977; Helle 198 1; National Council on Gene Resources 1982). To some, the fact that a wild fish was successfully angled and captured is aesthetically pleasing. Angling organizations such as Trout Unlimited and California Trout have been promoting the concept of wild trout fisheries for many years. There is presently an expanding constituency of anglers who fish for wild fish exclusively.

There are many experienced anglers who focus their attention on angling for particular stocks, such as the "blueback" steelhead of the central coast streams. There is also a growing constituency of non-anglers that appreciate the role and diversity of native fish by observing fish in the wild, or by simply knowing that a diversity of stocks and species exists as part of naturally functioning ecosystems.

GENETIC CONSIDERATIONS

To fishery managers, genetic conservation is as important to species preservation as is habitat conservation. Evolutionary biologists have known for some time the importance of genetic diversity: it is the "stuff" on which evolutionary change depends (Lewontin 1974, as cited in Krueger et al. 198 1) and the amount of genetic diversity is positively correlated with the rate of evolutionary change by natural selection (Fisher 1930, as cited in Krueger et al. 198 1). Experimental evidence for this relationship was provided by Ayala (1965, as cited in Krueger et al. 198 1). As previously discussed, genetic diversity supports the myriad of forms and behaviors within species, and along with species diversity and ecosystems diversity, comprise the concept of biodiversity. These three components are essential to the maintenance and health of the biosphere (Jensen et al. 1990).

Considerable scientific attention has been focused in recent years on the potential impacts of hatchery programs on genetics of wild populations (Reisenbichler and McIntyre 1977; Allendorf and Phelps 1980; Krueger et al. 1981; Leider et al. 1984, 1986; Chilcote et al. 1986; Waples et al. 1990; Hindar et al. 1991; Byrne et al. 1992). Evidence is becoming more and more conclusive that impacts to wild populations from hatchery introductions may be contributing to their decline: Miller et al. (1990), in an analysis of salmon and steelhead supplementation programs, found that "Adverse impacts to wild stocks have been shown or postulated for about every type of hatchery fish introduction where the intent was to rebuild the runs".

There are two main concerns regarding wild and native stock genetics: loss of genetic diversity (or variability) and reduction in average fitness in the population. It should be noted that genetic variability in hatchery populations is not necessarily less than that of wild populations (Allendorf and Ryman 1987), due to the increased survival of genotypes that would be selected against in a natural setting. However, loss of variability and reduction in fitness of the wild population can result from artificial production effects such as inbreeding, random genetic drift, artificial selection, adaptation to the hatchery environment, and hybridization. Loss of rare alleles due to reduction in the size and number of populations is another mechanism that can cause a decrease in genetic diversity and fitness.

Inbreeding and Genetic Drift. Inbreeding is the mating between related individuals. A population is said to be inbred when mating between relatives occurs at a frequency greater than that expected by chance. A small spawning population size and increased survival of progeny associated with fish culture can result in an inbred population. Inbreeding causes a reduction in genetic variability by increasing homozygosity. Fitness characters related to reproduction are most affected by inbreeding (Robertson 1955, as cited in Nelson and Soule 1987). The resulting reduction in survival, growth, fertility, and vigor, is termed **inbreeding depression.** Inbreeding depression is a serious problem facing managers of endangered fishes (Meffe 1986).

Aulstad et al. (1972) and Kincaid (1976), as cited in Hynes et al. (198 1), showed a reduced egg hatchability, survival of fry, and growth rates in inbred domestic strains of rainbow trout. Data on inbreeding effects include severe body deformities, growth reduction, behavioral changes, and reproductive failures (Meffe 1986). Inbreeding depression is mostly a problem in hatchery programs that maintain a captive broodstock, such as trout hatcheries, but can also be a problem in anadromous supplementation programs where small numbers of adults are spawned and a majority of them are of hatchery origin.

Geneticdrift is the change in allele frequencies of a population due to random chance. Genetic drift has its greatest effect on small populations: the smaller the number of breeders, the greater the chance that some alleles will not be represented in the breeding population. A small number of breeders is unlikely to represent the full range of genetic diversity of the population from which they came. This can result in the loss of genetic variability in populations (Futuyma 1986).

The importance of genetic drift as an evolutionary process has been the subject of debate. The neutralist view is that genetic variation is primarily due to random genetic processes while the selectionist view attributes such variation to natural selection. Nevertheless, in some instances genetic drift can be a driving mechanism for evolutionary change.

The fact that genetic drift has its greatest effect on small populations is of great importance for small rearing programs: even if the local population is used as broodstock, spawning of too few adults increases the chance that the selected spawners do not represent the full genetic diversity of the population. This can result in loss of genetic diversity in subsequent generations. Genetic drift is also a concern when genetically distinct and isolated populations reach critically low levels due to habitat degradation or destruction, over-fishing, or any other factors that depress the size of the breeding population.

The loss of genetic variability due to inbreeding and genetic drift in a population is determined by the effective number of breeders, or **the effective population size.** The effective population size is defined as the size of the breeding population that would lose genetic variability at the same rate as the actual breeding population (Allendorf and Ryman 1987). Effective population size is determined by the number of spawners, sex ratio, and ancestry of the population. An unbalanced sex ratio or inbred spawners will reduce the effective population size. For example, the loss of genetic variability through genetic drift for a spawning population of 99 females and one male will be as great as that of a population of only two females and two males. Either population has an effective population size of four (Allendorf and Ryman 1987). Also, the greater the genetic similarity of the spawners (that is, the more they are related) the smaller the effective population size.

To minimize the effects of inbreeding, Nelson and Soule (1987) suggest an effective population size of 50. Allendorf and Phelps (1980) contend that an effective population size of 50 will result in an expected loss of genetic variability of 1% per generation due to genetic drift. Although seemingly insignificant, this would result in a 10 % loss in variability over 10 generations. They recommend an effective population size of at least 100.

It should be noted that the preceding numbers are *effective population sizes* and a greater number of spawners will be necessary, especially if the sex ratio is unbalanced. Allendorf and Ryman (1987) recommend that a minimum of 100 males and 100 females be utilized for spawning. They also recommend using approximately the same number of eggs from each female and using one male to fertilize only one female.

Spawner population size is usually not a concern at DFG hatcheries, which must take between 200 and 500 female steelhead to meet their egg taking goals (based on 4,000 eggs per female). This is predicated on the assumption that an equal number of males are spawned. Small spawning population size is a concern, however, for the cooperative spawning and rearing programs that obtain their eggs from the local stock. Low numbers of returning fish on the smaller streams and difficulty in obtaining adults can result in an inadequate number of adults used for artificial spawning. Lack of knowledge and appreciation of genetic impacts can also lead to an inadequate number of adults used for spawning. For example, Mendocino County's Management Plan for the Lake Mendocino Hatchery Facility specifies a goal of 30,000 steelhead eggs to rear 15,000 fish to yearling size (Mendocino County 1992). To achieve this goal, they state they will need "six adult females... [and] several males." Clearly, genetic considerations didn't enter into the planning process: the number of adults needed appears to have been based solely on the assumed fecundity of female steelhead.

Artificial Selection. Selection for desirable traits tends to result in loss of genetic diversity. In the past, hatchery and fishery managers selected for larger, faster growing, early spawning individuals either because they possessed phenotypes desired by anglers or they were more suited to the hatchery environment. Selection for extreme phenotypes can result in a preponderance of homozygous genotypes (if the variation in the trait has a genetic basis) resulting in a loss of genetic variability. A reduction in fitness may also result because selection for desirable traits and the hatchery environment may adversely affect other traits by reducing frequencies of alleles that confer fitness to the natural environment.

Adaptation to the Hatchery Environment. Some selection in a hatchery program is unavoidable. Inadvertent artificial selection can result from selection against fish that survive poorly in the hatchery, regardless of whether their genotypes bestow fitness to the natural environment. Conversely, the most successful fish in hatcheries are those that are tolerant of crowding and readily accept hatchery food. If the increase in survival of juveniles resulting from an increased fitness to the hatchery environment leads to a greater return of adults to the hatchery, then the population can gradually become adapted to hatchery conditions and thus become domesticated. If natural selection has optimized fitness of a population to its particular habitat, then any change in selection pressures will not be beneficial in the long term (Meffe 1986).

Perhaps even more important, from the standpoint of changes in the genetic structure, is the relaxation of natural selection pressures that occurs when fish are cultured. This is particularly important because many supplementation programs in California use the local native population as broodstock. Because of this, there is a perception by some that the genetic integrity of the wild population is not compromised. Because of regular feedings, disease control, and other methods associated with artificial fish rearing, physiologically or morphologically "inferior" genotypes (in terms of fitness to the natural environment) that would be selected against in the wild may survive and contribute to subsequent generations. Allele frequencies of deleterious or "inferior" genes may be increased in subsequent generations, leading to a reduction in average fitness. This "release" from natural selection may contribute substantially to the deterioration of the population (Allendorf and Ryman 1987).

Although recent changes in hatchery management practices have shown a greater concern for genetic conservation, fish culture cannot reasonably approximate nature (Meffe 1992) or natural selection pressures. A hatchery stock developed from a wild stock can diverge substantially from the wild stock if wild fish are not continually included in the hatchery brood program (Reisenbichler and Phelps 1989). Even if wild fish are continually used as broodstock and strict protocols are implemented to maintain genetic integrity, genetic changes may be inevitable (Stickney 1994)

Hybridization. Two possible outcomes can result when an exotic strain of steelhead is introduced into a stream system containing an indigenous population: the exotic strain is so maladapted to the new environment that it persists for no more than a few generations, in which case there may be little impact on the indigenous population's genetic structure; or the exotic strain persists and some degree of gene flow occurs between the populations, resulting in introgression of the exotic stock's alleles into the indigenous population's gene pool. The exotic stock's alleles will most likely confer little fitness to the environment and may disrupt favorable gene complexes of the indigenous population (Allendorf and Leary 1988). This can reduce the fitness of the native stock (Helle 198 1; Thorpe et al. 198 1; Krueger et al. 198 1) and the resulting decline in overall fitness is known as **outbreeding depression.** There is a danger that even if an exotic stock is unsuited to the new environment, the genetic integrity of the indigenous population may be adversely compromised, especially if the number of exotic spawners greatly outnumbers native spawners (Chilcote et al. 1986).

Reduction in Population Numbers and Abundance. A decline in numbers within a population can result in a loss of rare and unique alleles. The loss of alleles permanently reduces the ability of populations to adapt to altered environmental conditions and can also reduce their resistance to disease (Allendorf and Leary 1988). Extinction of a local population permanently removes alleles from the species’ gene pool. This can reduce a species’ genetic diversity, the magnitude of which increases with the number of distinct populations that become extinct. If adaptations to a unique environment have a genetic basis, extinction would remove these rare and unique alleles from the species’ gene pool. This has become a major concern of those involved with Pacific salmon and steelhead restoration.

ARTIFICIAL PRODUCTION

There are seven DFG anadromous fish hatcheries that spawn and rear steelhead’, all located in northern California (Fig. 10). In addition, the U.S. Fish and Wildlife Service operates Coleman National Fish Hatchery. All, except Mad River Hatchery, are mitigation hatcheries, built and funded by federal and state water development agencies to mitigate for habitat lost from dam construction. Total steelhead production is approximately 3,150,OOO yearlings and 2,300,OOO fingerlings per year (Table 7).

In addition to the federal and state hatcheries, there are currently eight Cooperative Rearing projects that rear juvenile steelhead, administered through DFG’s Cooperatively Operated Fish Rearing Program. Total production from these facilities is about 375,000 yearlings per year. These projects have been staffed mostly by volunteers and are operated to produce steelhead for public benefit as part of DFG’s overall salmon and steelhead restoration program. Fish are obtained for rearing from artificial spawning of local populations, excess eggs from DFG’s hatcheries, or juvenile fish rescues.

’ There are eight DFG anadromous fish hatcheries, however, the Merced River Fish Facility does not have a steelhead program.

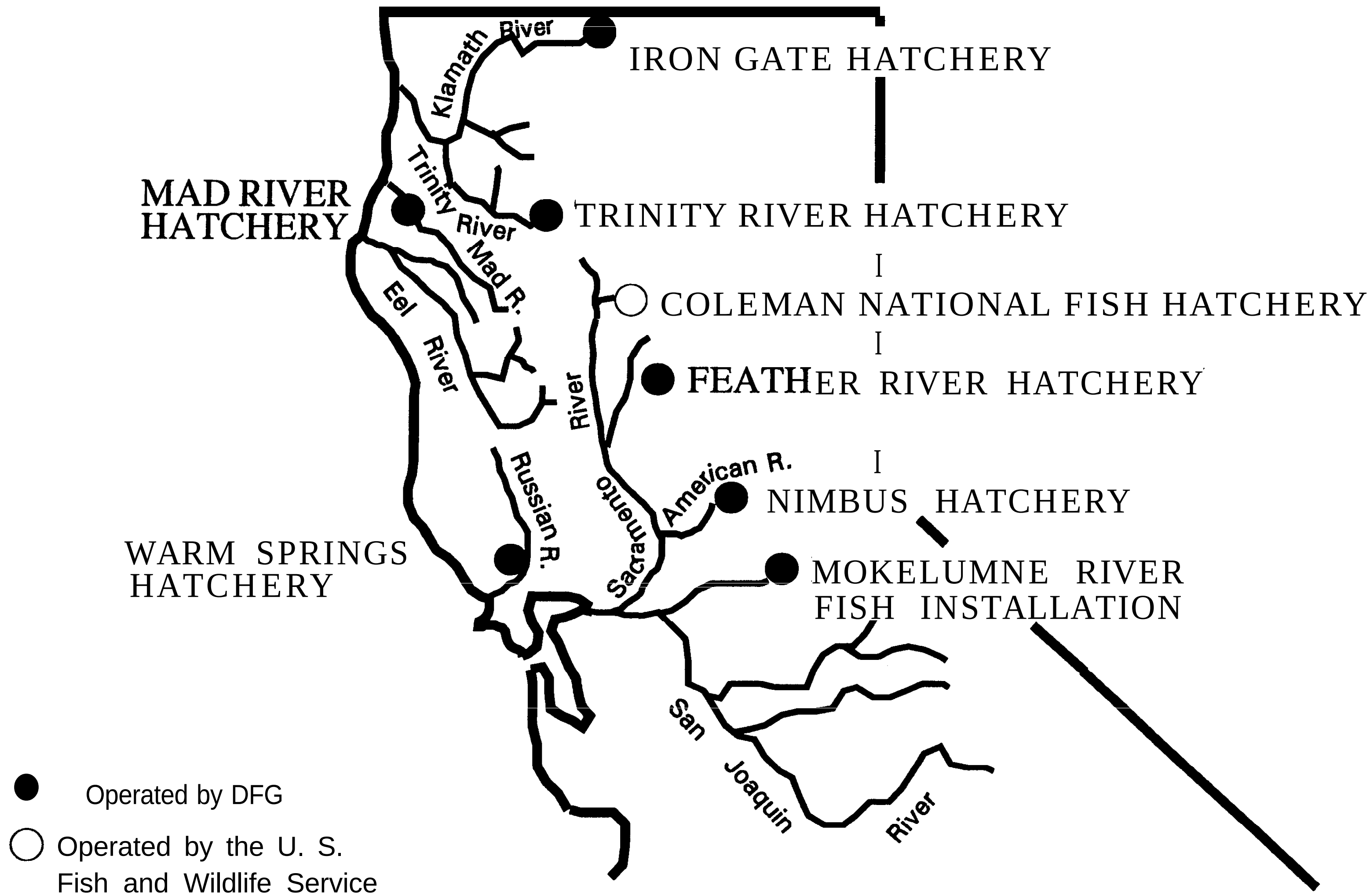


Figure 10. Anadromous fish hatcheries in California.

Table 7. Anadromous fish hatcheries and steelhead production in California. All are operated by the California Department of Fish and Game except Coleman National Fish Hatchery (U.S. Fish and Wildlife Service).

Facility (River System)	Purpose	Production Goal (Yearlings)	Average Annual Production 1984-85 through 1993-94	
			Fingerlings[1]	Yearlings
Iron Gate Hatchery (Klamath River)	Mitigation for Iron Gate Dam (Pacific Power and Light)	200,000	13,500	201,135
Mad River Hatchery	Enhancement	250,000	359,348	533,729
Trinity River Hatchery	Mitigation for Trinity Dam (USBR-Central Valley Project)	800,000	0	636,715
Coleman National Fish Hatchery (Sacramento River)	Mitigation for Shasta Dam (USBR-Central Valley Project)	700,000 to 800,000	245,378	526,602
Feather River Hatchery	Mitigation for Oroville Dam (DWR-State Water Project)	400,000 to 450,000	489,366	406,421
Nimbus Hatchery (American River)	Mitigation for Folsom Dam (USBR-Central Valley Project)	430,000	407,381	369,870
Mokelumne River Fish Installation [2]	Mitigation for Camanche Dam (East Bay Municipal Utility District)	100,000	35,734	179,125
Warm Springs Hatchery (Russian River)	Mitigation for Warm Springs Dam (U.S. Army Corps of Engineers)	460,000 to 500,000 [3]	734,085	291,625
Silverado Field Operations Base [4]	Planting base and quarantine facility	n.a.	16,630	5,183
All Hatcheries			2,301,422	3,150,405

[1] Includes fry, advanced fingerlings, and sub-yearlings.
[2] Because the steelhead run in the Mokelumne River is so small, eggs are procured from Nimbus Hatchery.
[3] Includes 160,000 to 200,000 yearlings raised at Coyote Dam Steelhead Facility.
[4] Silverado Base rears eggs and juveniles obtained from other facilities.

The role of artificial production in restoration and maintenance of anadromous salmonids has recently become a subject of controversy. Focused mainly on salmon studies in the Pacific northwest, several researchers have called for a fundamental rethinking of the role of hatcheries in rebuilding salmon and steelhead runs, the need for additional supplementation programs, and the way in which hatcheries are presently operated (Scarnecchia 1988; Meffe 1992; Hilborn 1992). Goodman (1990) has proposed that all hatcheries be regulated by the federal government to insure that uniform practices are implemented to prevent the further decline of wild stocks caused by impacts from artificially produced fish. Others argue that most hatchery-maintained populations are declining (Hilborn 1992) and that hatchery supplementation programs are not the panacea that will preserve anadromous Salmonid species and populations in the face of all environmental perturbations.

Despite the fact that many artificial propagation programs have succeeded in producing fish for harvest, they have generally not increased the abundance of wild fish (Hard et al. 1992). Miller et al. (1990), in an analysis of salmon and steelhead supplementation programs, found that "examples of success at rebuilding self-sustaining anadromous fish runs with hatchery fish are scarce. ' Of the 316 projects reviewed, they found that only 25 were successful at supplementing natural existing runs (although many were successful at returning adult fish). Aside from the aforementioned genetic impacts, these researchers cite other concerns regarding impacts to wild fish from hatchery programs: most notably competition, disease, over-exploitation, and continuing habitat loss.

Competition. Interspecific competition resulting from the introduction of an exotic species has probably been the most damaging to endemic populations. If there is overlap between the needs of an exotic and an indigenous species, displacement of the indigenous species can result if it lacks adaptive mechanisms necessary to cope with the new competitor. The decline of California golden trout (0. *m. aguabonita)* in number and range in the Kern River drainage subsequent to the introduction of brown trout *(Salmo trutta)* and the decline in distribution of brook trout *(Salvelinus fontinalis)* in Atlantic coast drainages as a result of competition with introduced brown trout, rainbow trout, and Pacific salmon (Goodman 1990) are two examples.

Intraspecific competition between wild and artificially cultured stocks can also result in wild fish declines. Although wild fish are generally more adept at foraging for natural foods than hatchery-reared fish, this advantage can be negated by the large numbers of hatchery fish released in a specific locale, and larger size and different behavior of the hatchery fish.

Disease. Crowded conditions in hatcheries can create favorable environments for many disease organisms. Introductions of exotic stocks can introduce a new disease into wild populations. The ability of a wild stock to cope with an introduced disease is reduced if the stock's genetic variability has been reduced through selection or genetic drift, because genes involved in the control of disease resistance have many alleles (Allendorf and Phelps 1980).

Over-exploitation. The relatively low number of spawners needed to sustain a hatchery population can result in high harvest-to-escapement ratios in waters where regulations are set according to hatchery production. This can lead to over-exploitation and reduction in size of wild populations coexisting in the same system. In a declared "hatchery management area" just north of Puget Sound in British Columbia, harvest rates on coho salmon (0. kisutch) are as high as 95 %. This is sustainable only because of the most successful hatchery stocks, and, as a result, wild stocks have declined (Hilborn 1992).

Continuing Habitat Loss. Meffe (1992) argues that hatcheries palliate the widespread loss and destruction of habitat and they conceal from the public the real problems facing our anadromous resources. Hilborn (1992) and Goodman (1990) echo this same sentiment. Moreover, Goodman (1990) contends that we have placed anadromous runs at risk by our heavy reliance on hatcheries because they themselves exist at the mercy of economic fluctuations, budget limitations, and political whims. Others argue that hatcheries consume vast amounts of money that could be better spent on habitat rehabilitation and acquisition and watershed improvements.

The positive aspect of California's anadromous hatcheries is that they have been very successful at providing fish for California's large sport angling population. Hatcheries have also been essential in maintaining steelhead runs in the Sacramento River system: steelhead would not exist in the Sacramento River system, in anything but remnant numbers, without the hatchery mitigation program. Steelhead, more so than salmon, are dependent upon headwater tributaries for successful spawning and rearing. Water development activities, particularly the construction of large dams at low elevations on the major Sacramento and San Joaquin river tributaries, has effectively rendered most of the Central Valley system unsuitable for natural spawning steelhead populations. The nearly complete absence of steelhead in the San Joaquin River system is a testament to the importance of a hatchery program in maintaining the Central Valley steelhead runs.

The intensity of the debate on the compatibility of wild and hatchery stocks has caused some to lose sight of the fact that artificial propagation is not responsible for the overall decline of natural stocks. Hatchery and propagation specialists react to this by accusing others of failing to adequately protect habitat, manage water resources to minimize impacts, and control over-harvest (Martin et al. 1992). This is causing a polarization among fisheries professionals that can hamper development and implementation of effective restoration strategies and erode public confidence in the ability of the fishery science profession to solve many of the problems causing decline of anadromous resources (Martin et al. 1992; Stickney 1994).

ARTIFICIAL PROPAGATION OF IMPERILED STOCKS

The decline of many native Salmonid stocks has prompted the development of a new role for artificial production facilities: assisting in the recovery of threatened, endangered, and declining stocks. When a native stock reaches critically low population levels, the need for immediate measures to prevent its extinction is paramount. Because of this urgency, artificial production facilities are often proposed in lieu of habitat restoration measures. Artificial production can be instrumental in rapidly rebuilding populations to avoid extinction, primarily by increasing reproductive success and juvenile survival. However, there are risks associated with using artificial production for this purpose, and its ability to supplement and restore natural populations is largely unproven (Hard et al. 1992).

There is a risk that operation of an artificial production facility to rebuild a depleted population can lead to a *de facto* hatchery mitigation program and, like fish rescue operations, can mask the real problems and delay implementation of long-term solutions for habitat restoration. Also, there has been a reluctance among some operators of Cooperative Rearing Projects in California to close down a facility that has been successful at achieving its goals. This problem is being addressed by requiring that all Cooperative Rearing Projects be operated in accordance with a 5-year management plan approved by DFG.

Other drawbacks include:

occurrence of genetic problems associated with fish culture;

risk of losing an entire year class due to adverse hatchery conditions or mass production and release of juveniles does little to restore populations if limiting factors are not addressed.

Despite the risks, artificial production programs are a necessity if the alternative is extinction. In this case, the risks posed by artificial production are outweighed by the need to rapidly increase abundance and avoid extinction. Artificial production is not a substitute for remedying the factors causing or contributing to the initial decline, and recovery programs should reflect integrated planning that addresses these factors (Hard et al. 1992).

The policy of the National Marine Fisheries Service (NMFS) on the use of artificial production to recover Pacific salmon populations (including steelhead) listed under the Endangered Species Act (ESA) is outlined in Hard et al. (1992). Artificial production may be consistent with the purposes of the ESA if it facilitates the recovery of a listed species. The ESA mandates the restoration and maintenance of threatened and endangered species in their natural habitats, hence focuses on recovery of habitat and ecosystems. Despite this emphasis, the ESA recognizes that conservation of listed species may be facilitated by artificial means, but a guiding principle for an ESA recovery plan should be to restore a viable population with the minimum amount of interference in its life history (Hard et al. 1992).

The Carmel River Captive Steelhead Broodstock Project was the only cooperative spawning and rearing facility in California operated solely for genetic conservation of a native steelhead stock. This program was necessary to guarantee the survival of the Carmel River steelhead strain and to speed its recovery. Another captive breeding facility has been proposed for Fillmore Hatchery on the Santa Clara River (see page 206).

REINTRODUCTION

Reintroduction of steelhead may be warranted on some stream systems where the native stock has been extirpated. In some instances where the native stock is extirpated from the anadromous reach it may still be extant in the upper reaches. The construction of impassable dams on many coastal tributaries has isolated rainbow trout populations upstream of the dams. Gall et al. (1990) analyzed allozymes from trout collected from Redwood and Kaiser creeks, tributaries to the Upper San Leandro Reservoir on San Leandro Creek (tributary to San Francisco Bay). They determined that the genetic profile of these fish more closely resembled that of coastal rainbow trout than any other California rainbow/redband trout group, and concluded that they are descendants of native California steelhead.

There are other areas along the coast where native steelhead, extirpated (or nearly so) from the anadromous reaches of a system, may persist in the landlocked upper reaches: above Del Valle, San Antonio, and Calaveras reservoirs in the Alameda Creek system; above Whale Rock Reservoir on Old Creek; and above Lake Cachuma on the Santa Ynez River. These are three areas that may harbor uncontaminated stocks of native steelhead that could be reintroduced downstream and possibly into nearby unoccupied stream systems.

Findings

- **Steelhead will be managed in accordance with recently enacted State mandates which place principal emphasis on natural production. Artificial production will only be considered for implementation in those systems where: 1) there are presently artificially maintained steelhead runs; 2) there is no longer a native or wild run and the habitat has been irrevocably altered; or 3) captive breeding is necessary to prevent the extinction of a native run.**
  We agree with the California legislature's finding that "*reliance upon hatchery production of salmon and steelhead trout in California is at or near the maximum percentage that it should occupy in the mix of natural and artificial hatchery production in the State.*" (Fish and Game Code of California, sec. 6901).

- **All steelhead produced in DFG hatcheries and Cooperative Rearing Projects will be marked so that they can be differentiated from wild fish. All Cooperative Rearing Projects must have provisions for marking in their 5-year management plans.**
  Despite evidence that hatchery supplementation programs can negatively affect wild stocks, we have no reliable means to differentiate hatchery from wild fish, hence we do not have a solid foundation to begin managing to protect wild stocks. Determination of origin based on fin erosion or scale analysis is not reliable or is impractical. The only reliable, practical means of identifying hatchery produced steelhead is to fin clip or otherwise mark them. Implementation of a marking program will allow a more expedient implementation of a selective harvest requirement, should one become necessary. Implementation of a marking program in the Central Valley should include Coleman National Fish Hatchery. Funds generated from *Steelhead Trout Catch Report-Restoration Card* sales may be used for this purpose, upon approval by the Steelhead Subcommittee of the California Advisory Committee on Salmon and Steelhead Trout. DFG should designate a Steelhead Tag Coordinator to keep track and assign marks used at the different hatcheries and rearing facilities.

- **Priority will be given to those Cooperative Rearing Projects that are part of an overall stream or watershed restoration program.**
  For the most part, these facilities are designed to supplement and restore natural production. Producing large numbers of steelhead without correcting the factors causing their decline is not in the best long-term interest of the resource.

- **DFG will continue with its habitat based approach for recovery of steelhead stocks.**

- **Artificial production to rebuild imperiled steelhead populations will only be considered for populations in imminent danger of extinction when no viable alternatives exist. These programs will have very specific goals and constraints that pertain solely to the stock of concern, will use temporary facilities or equipment, and will have an identifiable endpoint.**
  The NMFS guidelines (Hard et al. 1992) recognize the primacy of restoring habitat conditions necessary to maintain and recover declining populations. They make it clear that artificial production should not be a substitute for resolving the basic factors causing the decline of a population. Further, an artificial production program for recovery purposes should be viewed as a temporary measure, and discontinued when recovery goals are met or if there is evidence that the program is causing harm to the population or impeding its recovery.

- **Donor stock used for reintroduction will be the original stock or the most genetically similar stock.**
  Before introductions are implemented, genetic profiles of the donor stock should be examined to determine their relationship to the extirpated stock. Prior to reintroduction, perturbations that caused the extirpation must be addressed.

Recommendations

- ► **Water agencies and dam operators should attempt to meet deficient fishery mitigation requirements through more environmentally sound river regulation, including greater flow releases, and maintaining and restoring instream habitat.**
  Continued declines of hatchery-maintained runs may lead to increased artificial production so that escapement and mitigation goals can be met, which can cause an impact to wild juvenile survival. This would create a situation where increasing numbers of hatchery fish are released each year causing an even

greater depression of wild stocks, while not necessarily achieving a greater return of adults. The factors affecting the decline of hatchery stocks need to be addressed so that greater returns are achieved without resorting to increasing the number of juveniles released.

- **DFG hatcheries and the Cooperative Rearing Projects should be operated so that impacts to natural stocks are minimized (which includes setting planting allotments), and should be in accordance with the following guidelines:**

  * **For DFG hatcheries, a minimum of 100 males and 100 females should be used for spawning, wherever possible.**

  * **The Cooperative Rearing Projects will strive to maximize the number of adults they utilize for spawning, without adversely impacting natural spawning in the system.**
    In smaller stream systems, it may be difficult to obtain 100 adult fish of each sex for spawning and this number may, on some streams, exceed the number of natural spawners. Under these circumstances, the projects will be allowed to take no more than one-half of the run. This will be accomplished by conditioning DFG trapping permits so that traps can only be operated on a half-time basis when conditions are conducive to upstream movement of adults.

  * **Equal numbers of males and females should be used for spawning. One male should be used to fertilize the eggs of one female: eggs from multiple females should not be fertilized by sperm from one male.**

  * **Wild fish should be used for broodstock whenever possible to minimize the loss of genetic variability and to maximize fitness.**
    Hynes (1981) and Allendorf and Phelps (1980) recommend that a periodic infusion of genetic material from wild stocks be used to maintain genetic variability. Goodman (1990), citing the Alaska Department of Fish and Game (1985), states that indigenous wild adults should be used for broodstock whenever possible.

  * **To minimize artificial selection, spawners should be selected entirely at random and should not be chosen based on size or other "desirable" characteristics.**

The only exception to this is that spawners must meet the minimum size criteria currently established for each hatchery. This exception is necessary to avoid spawning non-native resident trout.

* **Egg take will be distributed proportionately throughout the entire spawning season.**
  All hatcheries should attempt to mimic natural spawn timing, which entails segregating egg lots by week of spawning. The percentage of the run spawned each week is calculated and the percentage of yearlings released from each week's egg take is based on these percentages. For example, if 15 % of the run spawned during the last week of January, then 15 % of the yearlings released will be from the adults spawned during that week. (Royce Gunter, DFG Fish Hatchery Manager II, pers. comm.)

* **Production from excess eggs will not be planted in excess of the overall production goals, except where approved for outplanting to restore other appropriate streams.**
  "Appropriate streams" are those within the same drainage that do not have naturally reproducing runs and where restoration of natural production is infeasible.

* **All production from DFG and Cooperative Rearing Projects will be released in accordance with the DFG Salmon and Steelhead Stock Management Policy.**
  Under existing DFG policy, out-of-basin stock transfers are not allowed under any circumstances for streams that still have a native stock. This policy will be strictly enforced. In order to insure compliance with DFG's management policies, the Cooperative Rearing projects will be required to adhere to the DFG Salmon and Steelhead Stock Management Policy and there will be no stock transfers without written approval from the Chief of the Inland Fisheries Division. All Cooperative Rearing projects operate under DFG approved 5-year management plans and permits issued by DFG regional offices. These permits can be revoked for violation of the five-year plans.

* **Steelhead raised in artificial production facilities should be planted downstream of wild steelhead rearing areas.**
  This is necessary to minimize competition and other impacts to wild fish.

ANGLING

CURRENT REGULATIONS

Steelhead angling usually begins in September or October and lasts through March. Open season for steelhead angling varies by stream: some streams are open year-round, however, there are many streams with more restrictive open seasons which allow fishing during only part of the year. In addition, there are many important spawning streams that are closed to angling year-round. In the South Central Sport fishing District (San Mateo, Santa Cruz, Monterey, and San Luis Obispo counties) many steelhead streams are open from November 16 through February 29, but only on Saturdays, Sundays, Wednesdays, and holidays. In some instances, minimum and maximum size limits are imposed on a particular stream to protect juvenile and adult steelhead from over-harvest.

angler-use information contained on the cards; updating the report card as necessary; and making management recommendations to restore and enhance California steelhead trout resources. Report card revenue, beyond that needed to support the project, will be used to fund restoration projects, gather new information on specific native steelhead stocks, and identify existing and potential problems. Expenditure of funds is guided by the Steelhead Subcommittee of the California Advisory Committee on Salmon and Steelhead Trout.

ADULT HARVEST

There is little information on steelhead harvest rates in California. The limited catch statistics that are available indicate that sport harvest rates may be lower than they were in the 1950's and 60's. Hallock et al. (1961) estimated that harvest rates for Sacramento River steelhead from the 1953-54 through 1958-59 seasons ranged from 25.1% to 45.6 % , assuming a 20 % nonreturn rate of tags. Staley (1976) estimated the harvest rate in the American River during the 1971-72 and 1973-74 seasons to be 27 % . The average estimated harvest rate on adult steelhead above Red Bluff Diversion Dam for the three year period 1991/92 through 1993/94 is 16 % (DFG unpublished data).

Harvest rate estimates for the Klamath River for the 1977-78 through the 1982-83 seasons ranged from 7.4 % to 19.2% and averaged 12.1% (CDFG unpublished data). Harvest rates for wild steelhead are similar: wild steelhead in the Trinity River were harvested at rates of 28.0%, 12.5%, and 17.3% in the 1978-79, 1980-81, and 1982-83 seasons, respectively (CDFG, unpublished data), and sport harvest of wild steelhead in the South Fork Trinity River was estimated to be 5.9%, 18.0%, 8.0%, and 20.2% during the 1988-89, 1989-90, 1990-91, and 1991-92 seasons, respectively (Mills and Wilson 1991; Wilson and Mills 1992; Wilson and Collins 1992; Collins and Wilson 1994) (Table 8). In contrast, sustainable harvest rates on Pacific salmon stocks often exceed 50% (Alan Baracco, DFG Senior Marine Biologist, pers. comm.).

The evidence that harvest rates are declining statewide is inconclusive because of the lack of historical data and the limited estimates that are currently available. It appears, however, that over-exploitation of wild stocks is not occurring on a widespread basis and is not causing the overall decline in steelhead stocks. It is possible that localized over-exploitation is occurring without our knowledge on specific stream systems. There is limited data that suggests that unfished north coast streams are more productive than tributaries of fished rivers (Larry Preston, DFG Associate Fishery Biologist, pers. comm.).

Because of declining steelhead populations and harvest rates, Oregon has adopted a statewide selective harvest regulation, i.e. zero bag limit for wild adult steelhead. All hatchery produced juvenile steelhead are marked prior to release and anglers are required to

Table 8. Estimated steelhead sport harvest rates (%) in the Klamath - Trinity system.

[illegible]										8.0[6]	8.0[7]	ZO.Z*

[1] Estimates from Klamath-Trinity Project (DFG, unpublished data).

[2] 77/78 to 89/90 estimates from DFG Trinity River Project staff; 90/91 estimate from Heubach et. al 1992; 91/92 estimate from Lau et. al 1994.

[3] Above Junction City Weir.

[4] Above Willow Creek Weir.

[5] Source: Mills and Wilson 1991.

[6] Source: Wilson and Mills 1992.

[7] Source: Wilson and Collins 1992.

[8] Source: Collins and Wilson 1994.

release all unmarked adult steelhead unharmed. Juveniles stocked in each system are marked with a unique combination of fin clips to evaluate adult returns and degree of straying (Mick Jennings, Oregon Department of Wildlife, pers. comm.). In the near future, all but 17 out of nearly 200 Oregon streams will be managed for wild catch-and-release (Mick Jennings, pers. comm.). This program is popular among Oregon anglers.

Selective harvest regulations allow for the protection of wild stocks from over-harvest while not significantly infringing on angler opportunities. Proponents argue that implementation of a selective harvest regulation can only be beneficial and that we should begin taking a conservative approach to the management of wild stocks.

Opponents of selective harvest regulations in California argue that marking all hatchery fish is too costly, marking-related stress will cause a decrease in production, and finclipping will interfere with coded wire tag studies. All of these problems can be effectively managed however, should a selective harvest regulation be implemented. The only factor that should be considered is need: if wild stocks are declining due to excessive harvest, then a selective harvest regulation should be implemented. The only other viable alternative may be to close the fishery. This sentiment is expressed by Larkin (1979, as cited in Wright 1993): "Under no circumstances should the permissible harvest of any race of salmon be exceeded. Day-to-day regulation should be geared to salmon biology, not human convenience."

Implementation of the Steelhead Trout Report Restoration Card will provide much-needed information on harvest rates. The need for a selective harvest requirement, either statewide or local, should be evaluated when these data become available. It should be noted however, that implementation of a selective harvest program would have a lag time of at least two years from the time of initial marking of the hatchery-reared fish, unless a marking program is instituted beforehand.

- **Based on the limited harvest estimates that are available, a statewide selective harvest regulation does not appear to be warranted at this time.**
  However, this conclusion is tenuous, and should be reevaluated when information from the Steelhead Trout Report-Restoration Card becomes available. Sport harvest needs to be evaluated on rivers and streams other than the Klamath and Trinity systems and, if necessary, a selective harvest regulation on a system-by-system basis should be instituted.

- **Currently, there is no substantial documentation that broad-scale angler harvest of adult steelhead is excessive and detrimental to California steelhead populations, therefore adoption of an annual bag limit for steelhead is not recommended.**
  The Steelhead Catch Report-Restoration Card will provide much needed information about harvest data on which to base an analysis of harvest impacts. The need for an annual bag limit will be reevaluated when this information becomes available.

The lack of information on sport harvest rates in California does not belie the fact that over-harvest may be, or has been, occurring on a local basis. Angling regulations were recently adopted for several critical streams that should preclude take of adult and juvenile steelhead. These regulations are discussed in the Central Valley and South Coast Management Objectives sections of this plan.

JUVENILE HARVEST

Steelhead life history typically includes rearing in freshwater for at least one year; therefore, juveniles typically reach catchable length before migrating to the ocean and are often taken by anglers. Angling harvest may reduce the ultimate yield of adult returns.

Larger age 2+ wild steelhead are particularly susceptible to harvest by anglers. In northern Idaho, Pollard and Bjornn (1973) found that a majority (70-100%) of the larger juvenile steelhead within catch-and-remove sections of their study were caught after four angler-hours of effort and age 1 steelhead were less susceptible (4-12%) to angler harvest.

Particular locations are targeted by anglers because of stocking practices, accessibility, and fish abundance. River flow conditions greatly affect angler effort and harvest rate. Angler effort and juvenile steelhead harvest were particularly high in portions of the Central Valley from January through March, 1992 because of low flow conditions (Frank Fisher, DFG Associate Fishery Biologist, pers. comm. ; Larry Hansen, DFG Fishery Biologist, pers. comm.). Conversely, flows were high during 1993 and angler effort and harvest were nearly zero (Larry Hansen, pers. comm.).

Little information exists regarding angler harvest of juvenile steelhead trout in California waters. The limited harvest information that is available primarily pertains to hatchery-reared juveniles, predominately within the Central Valley system. Although some studies have been undertaken to determine harvest rates of juvenile hatchery steelhead (Staley 1976; Menchen 1980), more recent information is mostly from personal observations of DFG biologists and wardens.

In 1972-73, DFG conducted a study to estimate the freshwater sport catch of Coleman Hatchery yearling steelhead stocked at two sites in the upper Sacramento River system (Menchen 1980). A total of 1,448,610 yearling steelhead, including 5,993 with reward and non-reward tags, was released in Battle Creek at Coleman Hatchery and in the Sacramento River at Balls Ferry. A majority of the juvenile catch was within the first 50 miles downstream from the release sites. Based on the tag returns, it was estimated that 2.7 % of the steelhead released at both locations were caught before they reached the Delta.

Staley (1976) found that 5 1.2 % of Nimbus Hatchery yearling steelhead that were released in the American River were caught by anglers as juveniles. Nimbus yearlings released in the Sacramento River were harvested at much lower rates, however.

Biologists with DFG's Sacramento River Angler Survey reported that harvest of hatchery juvenile steelhead is high in the upper Sacramento River from January through March (Larry Hansen, pers. comm.). A large number of bank anglers, targeting stocked juvenile steelhead, habitually appear as far downstream as Chico shortly after the fish are planted. Anglers often take as many as 10 juvenile steelhead per day each (Larry Hansen, pers. comm.). Catch rate of juvenile steelhead near the Deschutes Road Bridge has reached as high as 30 fish per hour. In February of 1992, four anglers caught a total of 70 juveniles in 7.5 hours (DFG Sacramento River Angler Survey, unpublished data).

The Sacramento River has several locations where anglers can easily access the river and find concentrations of stocked juvenile steelhead. Releases near Red Bluff Diversion Dam typically attract numerous anglers that do not observe the three fish daily bag limit (Larry Hansen, pers. comm.). Nimbus Fish Hatchery release yearling steelhead at Clarksburg and Garcia Bend and significant harvest of juveniles occurs at the release sites.

Battle Creek is frequently an area of intense juvenile steelhead harvest by anglers. On opening day in 1991, approximately 80 boats were fishing at "the Barge Hole" (Larry Hansen, pers. comm.). Because of the 1992 low water levels, as many as 90 % of the stocked juvenile steelhead were harvested from Battle Creek by anglers (Frank Fisher, pers. comm.).

Juvenile steelhead were also taken in the Feather River near Yuba City (Bill McFarland, DFG Warden, pers. comm.; Fred Meyer, pers. comm.; Lynn Wixom, DFG Associate Fishery Biologist, pers. comm.). Juvenile steelhead are stocked annually at the

Yuba City and Boyd's Pump boat ramps, which sometimes creates difficulties for boaters attempting to use the ramp because of the large numbers of anglers fishing from the dock and ramp (Bill McFarland, pers. comm.). Juvenile steelhead remain near the dock for several days, then migrate downstream to Shanghai Bend, apparently a preferred holding location.

- **The Fish and Game Commission should adopt a minimum size restriction of eight inches. for rainbow trout in anadromous waters.** Excessive harvest of wild juvenile steelhead may be contributing to decline in adult returns in specific streams. Increased wild steelhead smolt yield may be important to the recovery of California's wild steelhead populations and fishery. Few wild juvenile steelhead in freshwater exceed 8 inches in length (Pollard and Bjornn 1973). In the Trinity River basin, Wilson and Collins (1992) reported that the maximum size measured for age 2+ steelhead was 230 mm FL (9 inches) and the mean FL ranged from 153 mm (6 inches) to 185 mm (7 l/4 inches). The need for bar-bless hook restrictions should be evaluated for specific streams and, if necessary, implemented.

STEELHEAD ANGLING TOURNAMENTS

Organized competitive sport fishing (e.g., tournaments and derbies) has become a growing use of fishery resources throughout the United States for at least the last 20 years (Schramm et al. 1991). Of the 3 18 annually permitted events in California, 77 % were for centrarchid bass, 9 % were for trout, 7 % were for striped bass, and 3 % were for catfish (Schramm et al. 1991). For the 3 18 events, **77%** were one-day events, averaging 178 participants; the minimum number of participants recorded was four and, the maximum was 3,600 (Schramm et al. 1991). There are no written reports of any tournament activity prior to 1988.

Permitted steelhead tournaments in California are a relatively new and infrequent activity. DFG requires tournament sponsors to submit a permit application to the DFG and, if approved, a summary report must be submitted after the tournament's completion. As of February 1993, a total of 13 steelhead contest permits was issued by the DFG. A total of 361 steelhead was reported caught from California rivers during the 13 tournaments; 119 (33 %) were kept and 242 (67%) were released.

Competitive fishing can deplete fish populations through intensive harvest on selected waters (Schramm et al. 1991). In addition, intensive harvest may cause a general loss of genetic diversity by, for example, selecting for larger, fast-growing fish which might alter the population genetics in favor of slow-growing genotypes (Schramm et al. 1991). Data gathered and analyzed from the Steelhead Catch Report-Restoration Card and other information sources should provide additional information regarding the effects of tournaments on steelhead populations.

More restrictive regulations may be necessary to protect steelhead from over-harvest, while still allowing anglers the opportunity for continued competitive sport fishing. Upon review of individual tournament permit applications, DFG may implement one or more of the following guidelines:

- **Catch and Release Only.**
  All steelhead will be released unharmed. Caught fish cannot be kept in live wells

managed as put-and-take fisheries for domesticated hatchery trout. Population and habitat surveys and angler harvest data are used to assess the quality of the stream or lake to determine its appropriateness for designation as a Wild Trout or Catch-and-Release water. These waters cannot be stocked with domestic strains of trout. Special regulations and reduced bag limits are often implemented to maintain quality angling values for individual waters.

Presently, there are three steelhead streams designated as Catch-and-Release and none designated as Wild Trout: nearly all of the current waters in these programs are inland waters designated for their outstanding value as resident trout fisheries. However, the *Trout and Steelhead Conservation and Management Planning Act of 1979,* specifically includes steelhead trout. Streams that have outstanding value as wild steelhead fisheries should be managed accordingly.

- **DFG will begin assessing steelhead streams to determine their appropriateness for placement in the Wild Trout or Catch-and-Release Programs.**
  Some streams that should be considered are the Big Sur, Yuba, Mattole, Mad, Klamath, and Smith rivers and Redwood Creek (Humboldt County).

OCEAN LIFE HISTORY

Researchers have made significant progress over the last several decades in understanding the relationship between the marine environment and anadromous fish population dynamics. Most of the published information pertains to salmon in the North Pacific Ocean: little is known about steelhead. Pearcy (1992) provides a concise summary of information regarding ocean ecology of North Pacific salmonids.

DISTRIBUTION AND MIGRATION

California steelhead spend from several months to three years in the Pacific Ocean before returning to freshwater. Approximately 47 % and 35 % of the spawning adults in Waddell Creek had spent one and two years at sea, respectively (Shapovalov and Taft 1954). The age composition of high seas steelhead is also dominated by one (61.9 %) and two (31.4%) year ocean fish, with a maximum of six years at sea (Burgner et al. 1992). Steelhead exhibiting the half-pounder life history go to sea for only a few months, then return to freshwater but do not spawn (Kesner and Barnhart 1972).

Soon after North American steelhead smolts enter the Pacific Ocean in the spring, they quickly begin a directed movement into offshore pelagic waters of the Gulf of Alaska (Light et al. 1989). Steelhead generally follow a counter clockwise migration pattern in epipelagic waters east of 167°E longitude (Light et al. 1988), primarily within 10 m (33 ft) of the surface (Light et al. 1989) but have been found as deep as 23 m (Burgner et al. 1992). The southern limit of steelhead migration, while feeding and growing prior to returning to freshwater, is approximately 38°N latitude (roughly Point Reyes) and is closely associated with the 15°C (59°F) sea surface isotherm (Light et al. 1989; Burgner et al. 1992). The northern distribution extends slightly north of the Aleutian islands and does not appear to be influenced by water temperature (Light et al. 1989; Burgner et al. 1992; Pearcy 1992).

Steelhead stocks from Alaska to California are widely dispersed, extensively intermingled, and show little or no differences in ocean distribution (Light et al. 1988 and 1989; Burgner et al. 1992; Pearcy 1992). Of the 1,722 adult steelhead that were captured in the open ocean, disk tagged, and released during the 1956 to 1988 (32 years) International North Pacific Fisheries Commission (INPFC) high seas tagging experiments, nine of the 77 North American tag recoveries were from California streams (Burgner et al. 1992). These fish were tagged and released between 136°W and 157°W latitude and 45°N and 54°N longitude from June 1961 to May 1965 (Light et al. 1988). Of the nine steelhead recovered in California waters (all between July 1963 and November 1967), four were reported as unknown recovery location. Based on the coordinates given for the four unknowns, these fish were caught in the Mad River, Mill Creek (Mendocino County), Eel River, and South Fork Eel River drainages. The other five fish were recovered in the Van Duzen, Carmel, and Russian rivers, Alder Creek (Mendocino County), and near Crescent City (Light et al. 1988).

Over 138 million steelhead were tagged/marked at North American hatchery facilities between 1978 and 1989 (Burgner et al. 1992). In California, an average of 200,000 coded-wire tagged (CWT) steelhead were released yearly between 1980 and 1985 (Johnson and Longwill 1988, as cited in Burgner et al. 1992). No CWT steelhead from California have been recovered on the high seas (Burgner et al. 1992). A single 1982 brood-year steelhead, released during March 1983 in the Feather River at Yuba City, was recovered near Petersburg, Alaska at 55°N and 131°W during August, 1983 (Burgner et al. 1992, updated unpublished data).

Half-pounders most likely do not travel a great distance offshore before returning to

JUVENILE MORTALITY

Steelhead experience most of their marine phase mortality soon after they enter the Pacific Ocean (Pearcy 1992). Ocean mortality is poorly understood, however, because few studies have been conducted on this vast body of water. Possible causes of juvenile steelhead mortality are predation, starvation, osmotic stress, disease, and advective losses (Wooster 1983; Hunter 1983, both cited in Pearcy 1992; Pearcy 1992). Advective losses (mortality associated with the divergence of water currents which disperses nutrients and organisms that greatly depend on physical transport rather than active swimming) are likely lower for juveniles that enter the sea at a larger size (Pearcy 1992). Predation is probably the primary cause of marine mortality of juvenile steelhead, and mortality and fish size are presumably inversely related (Pearcy 1992). Known potential predators of juvenile chinook and coho salmon, and presumably juvenile steelhead, in marine or estuarine waters in Oregon include 29 species of fish, 36 species of birds, and eight species of mammals (Cooper and Johnson 1992).

Warm temperatures and low salinities have been correlated with poor survival of coho and chum salmon smolts (Holtby and Scrivener 1989; Holtby et al. 1990, both cited in Pearcy 1992). Pacific hake *(Merluccius productus)* and Pacific mackerel *(Scomber japonicus)* possibly invade nearshore areas and prey intensely on juvenile salmonids during warm water years (Holtby and Scrivener 1989; Holtby et al. 1990, both cited in Pearcy 1992). Coho survival may be influenced by river flow patterns (Pearcy 1992).

The Columbia River drainage has been greatly affected by dams and storage of water which have reduced the peak flow during the spring, retarding the downstream migration of smolts and affecting the size and structure of the Columbia River plume during the spring and early summer when coho (and steelhead) smolts enter the ocean (Francis et al. 1989, as cited in Pearcy 1992). A strong plume allows juveniles to expend less initial energy to migrate, and allows for a greater and quicker distribution throughout the marine environment. It is possible that reduced spring outflows of highly regulated rivers have decreased the extent of cold freshwater plumes into the Pacific Ocean, which would have otherwise disbursed the juveniles further offshore.

ADULT MORTALITY

Marine mortality of adult steelhead may occur from authorized and unauthorized high seas driftnet fisheries, predation, competition, and environmental conditions in the ocean (Cooper and Johnson 1992).

Authorized High Seas Driftnet Fisheries

Based on recoveries of marked/tagged North American steelhead (Light et al. 1988; Burgner et al. 1992), high seas steelhead distribution and driftnet fisheries overlap. The recent decline in steelhead abundance along the Pacific coast may be partially attributed to the harvest of steelhead in high seas driftnet fisheries (Cooper and Johnson 1992). The Japanese salmon driftnet fishery (mothership and landbased) closed in 1991 and the high seas squid driftnet fishery was closed at the end of 1992.

The authorized Japanese mothership salmon driftnet fishery was largest between 1973-1977 when a total of 2 1.4 million salmon were harvested per year (Cooper and Johnson 1992). The authorized Japanese landbased salmon fishery harvested 30.2 million fish per year (Cooper and Johnson 1992). The number of steelhead reported in the catch ranged from 2,761 in 1990 to 28,911 in 1983.

Cooper and Johnson (1992) estimated that less than 1% of the total Salmonid catch in both of the authorized Japanese salmon driftnet fisheries were steelhead. The authorized Japanese salmon driftnet fisheries were primarily east of longitude 175°E. Based on limited tag recovery information for California steelhead, 157°W is the furthest west California steelhead are known to migrate, hence they may not have been influenced by this fishery.

The authorized high seas neon flying squid *(Ommastrephes bartrami)* driftnet fishery was operated by, Japan, the Republic of Korea, and Taiwan (Cooper and Johnson 1992). By 1988, approximately two million miles of squid driftnet were set per year (Benton 1990, as cited in Cooper and Johnson 1992). The Salmonid catches and the number of Salmonid “dropouts” during net retrieval for the 1990 squid driftnet fishery was estimated by Pella et al. (1991): the Korean and Taiwanese steelhead bycatch was negligible with 35 and two steelhead harvested, respectively; the total estimated Salmonid bycatch in the authorized Japanese squid driftnet fishery was 210,000 fish caught and 21,000 dropout fish. The estimated steelhead harvest in this fishery in 1990 was 9,200 (range 2,000 to 16,800), or 4 % of the total bycatch (Pella et al. 1991).

An estimated 1.6 million steelhead adults return to the Pacific coast of North America (Light 1987; Burgner et al. 1992). The combined authorized high seas driftnet fisheries caught less than 3 % of the adult steelhead returning to the Pacific coast of North America from 1983 through 1990 (Cooper and Johnson 1992).

Unauthorized High Seas Driftnet Fisheries

Unauthorized fishing on the high seas can potentially cause a substantial level of Salmonid mortality (Pella et al. 1991; Cooper and Johnson 1992). A total of 7 1 and 165 foreign vessels was observed outside authorized fishing areas in 1990 and 1991, respectively (NOAA-NMFS 1991, as cited in Cooper and Johnson 1992). Cooper and Johnson (1992) estimated that the unauthorized high seas driftnet fisheries harvest between 2% (32,000) and 28% (448,000) of the steelhead that return to the Pacific coast of North America. Using this range and assuming there were approximately 250,000 California adult steelhead, an estimated 5,000 to 70,000 California steelhead were harvested in this fishery. This assumes that all fish have an equal chance of being harvested, which may not be a valid assumption.

Based on tag returns to California streams from the high seas steelhead tagging study, Hallock (1989) estimated that 24,600 California steelhead were killed annually by the squid fishery, or 12.3 % of an "estimated" 200,000 steelhead that were harvested by the North Pacific squid fishery. The 12.3 % estimate is based on a return of nine tags in California, out of 73 high seas tag returns to Pacific Coast streams[1]. If North American steelhead stocks are extensively intermingled with little or no differences in ocean distribution (Light et al. 1988 and 1989; Burgner et al. 1992; Pearcy 1992), then Hallock's assumption that random tagging of steelhead on the high seas would lead to equal opportunity of tag recovery seems reasonable.

It is curious why no tagged steelhead have returned to California since 1967. Several possibilities exist. Perhaps none were returned even when a fish was caught or a carcass found. The Fisheries Research Institute (FRI) conducted a drawing for several large cash prizes during March 1993 (and will possibly continue the drawings annually) for all high seas tags recovered and returned. Possibly, California steelhead populations are lower than estimated, are not evenly distributed in the Pacific, and/or have a differential mortality rate subsequent to tagging from stress or disease associated with warmer water temperatures. Depending on the population size and distribution of California steelhead in the Pacific Ocean, harvest of California steelhead by the high seas driftnet fisheries may be (and have been) minimal. Even if the high seas driftnet fisheries harvested a combined 3 1% (3 % authorized and 28 % unauthorized) of the steelhead, the 50% decrease in North American steelhead runs observed between 1986-87 and 1990-91 cannot be solely attributed to this fishery (Cooper and Johnson 1992).

' As stated previously, Burgner et. al (1992) state there were 77 North American high seas tag recoveries. We assume the discrepancy is due to the recovery of additional tags after Hallock did his analysis.

Predation

Pinnipeds, in particular the California sea lion *(Zalophus californianus),* the Stellar sea lion *(Eumetopias jubatu),* and the Pacific harbor seal *(Phoca vitulina),* are often accused of consuming or injuring large numbers of salmonids and have a bad reputation with anglers (Beach et al. 1985, as cited in Cooper and Johnson 1992). Pinnipeds are primarily opportunistic and feed on schooling fish (e.g., herring, perch) and sedentary fish (e.g., sole, sculpin) in the marine environment (Brown and Mate 1983). Roffe and Mate (1984), found that pinnipeds fed opportunistically on fast swimming salmonids and less than 1% of the adult Rogue River (Oregon) summer steelhead were preyed on during their upriver spawning migration. Salmonids appear to be a minor component of the diet of marine mammals (Scheffer and Sperry 1931; Jameson and Kenyon 1977; Graybill 1981; Brown and Mate 1983; Roffe and Mate 1984; Hanson 1993). Principal food sources are lampreys (Jameson and Kenyon 1977; Roffe and Mate 1984), benthic and epibenthic species (Brown and Mate 1983), and flatfish (Scheffer and Sperry 1931; Graybill 1981).

Although predation on steelhead by marine mammals occurs, it is not likely an important factor in the coastwide steelhead population decline (Cooper and Johnson 1992). Based on catch data, some of the best catches of coho, chinook, and steelhead along the Oregon coast occurred after marine mammals, kingfishers, and cormorants were fully protected by law (Bayer 1989, as cited in Cooper and Johnson 1992).

Predation by California sea lions can have an adverse impact on local steelhead populations, particularly in areas where the fish are concentrated and provide greater opportunity for predation (Cooper and Johnson 1992). Pfeifer (1987), as cited in Cooper and Johnson (1992), estimated that 43 % of the steelhead run into the Lake Washington system (Washington) was lost due to sea lion predation during the 1986/87 season, and he attributes the low escapement to these high predation rates. Predation appears to be greatest where adult steelhead are blocked or hindered in their migration and individual sea lions become accustomed to feeding on them.

Low flow conditions in streams can enhance predation opportunities, particularly in southern California streams, where adult steelhead may congregate at the mouths of streams waiting for high flows that will make the stream accessible. In addition, warmer water temperatures may affect steelhead mortality from predation directly or indirectly through stress and disease associated with wounds inflicted by pinnipeds.

Competition

Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992). Pacific hake and Pacific salmon could be competitors for the same food resource, and presumably with steelhead as well (Light 1985; Myers et al. 1990, both cited in Cooper and Johnson 1992; Cooper and Johnson 1992). Abundant releases of hatchery salmonids may increase competition and decrease survival and/or growth of hatchery and wild salmonids in the ocean (Cooper and Johnson 1992). During years of low ocean productivity (i.e., weak upwelling), smolt-to-adult survival rates indicated that increased competition and mortality occurred when large numbers of hatchery and wild smolts were combined (McCarl and Rettig 1983; Peterman and Routledge 1983; McGie 1984; Lin and Williams 1988, all cited in Pearcy 1992). Weak upwelling brings fewer nutrients from the ocean bottom to the surface, therefore primary and secondary productivity is low.

Environmental Conditions

Oceanic and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological and chemical processes in the marine environment. "Subtle changes in key environmental parameters (e.g., ocean currents, wind speed and direction, and presence of predators) or large-scale changes (e.g., global warming) can alter abundance, distribution, and availability of fish populations" (Glantz 1990, as cited in Cooper and Johnson 1992).

The Alaska and California currents influence the biological production at all levels of the food chain in the North Pacific (McLain 1984; Francis and Sibley 1991, both cited in Cooper and Johnson 1992). The north flowing Alaska Current and the south flowing California Current are separated by the Subarctic Current. The strength and relative proportion of these currents can dramatically affect Salmonid production along the continental shelf (Pearcy 1992).

El Niño and reduced Salmonid production are often discussed in the same breath. El Niños are episodic and vary in intensity (Pearcy 1992). Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1992). During El

Alaska is large (e.g., Aleutian atmospheric low pressure is strongly developed), and the subarctic influence in the California Current is decreased (Pearcy 1992).

For juvenile steelhead, warmer water and weakened upwellings are possibly the most important of the ocean conditions associated with El Nifio. During the 1982433 El Nifio event, juvenile salmon distribution was shifted northward: few juvenile coho salmon were found off the Oregon and southern Washington coast and catches were high off the northern Washington coast (Pearcy 1992). During an El Nino year, juvenile California steelhead would need to migrate further north to find the preferred cooler water temperatures. Because of the weakened upwelling during an El **Niño** year, juvenile California steelhead would need to more actively migrate offshore through possibly stressful warm waters with numerous inshore predators. Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1992).

In addition, survival of maturing or adult steelhead may be affected by El Nifio events. Pearcy et al. (1985) and Johnson (1988), both cited in Pearcy (1992), reported that 58 % of the predicted Oregon adult coho production in 1983 died during their last year in the ocean. El Nifio events may be highly stressful to California steelhead because they must travel through an abnormal amount of warm and relatively unproductive water.

The ocean is a complex system with many factors, both natural and human-influenced, that fluctuate primarily independently. Reliable prediction of the magnitude of salmonid populations returning to the North Pacific coastal streams may not be possible; rather, it may only be possible to predict the direction of change in salmonid populations (Cooper and Johnson 1992).

- **It is essential that steelhead management and recovery efforts focus on factors affecting freshwater life history, since ocean life history is not as significantly affected by human activity.**
  There are probably many factors affecting the ocean life history of California steelhead, of which we have little knowledge and almost no control. Conversely, there is much evidence regarding the degradation of freshwater habitat and the detrimental effects that this has had on steelhead populations.

- **Research on marine factors that may have an influence on steelhead survival should be continued.**

POLICY ISSUES

In June of 1993, the Fish and Game Commission (FGC) adopted DFG's recommended changes to the *Steelhead Rainbow Trout Policy*. These changes were designed to update the policy and to bring it into better conformance with other policies and Fish and Game Codes. Because FGC policies provide guidance of a general nature, more specific DFG management guidelines are needed.

- **The following will be adopted as Department of Fish and Game Policy:**

  STEELHEAD RAINBOW TROUT MANAGEMENT POLICY

  Restoration of native and wild stocks is the highest priority for steelhead management. Management emphasis shall be placed on assessment of status, protection of populations and habitat, and restoration.

  The greatest threat to this resource is freshwater habitat loss and degradation. The key to preserving habitat is to maintain adequate stream flows, including sufficient flows to provide access between ocean and freshwater environments. Steelhead restoration and management plans should contain the following elements, where appropriate:

  > *Provisions for adequate streamflows through enforcement of appropriate Fish and Game codes and other statutes, and negotiations with water agencies and. water users.*
  >
  > *Acquisition of important habitats and water rights.*
  >
  > *Restoration of access to historical spawning and rearing areas through barrier modification, fishway installation, or other means.*
  >
  > *Recommendations for watershed protection and land use practices.*

  All available steps shall be taken to prevent loss of habitat. Because estuaries and lagoons provide important juvenile rearing habitat, especially in small coastal stream systems, the Department will seek to protect and restore estuarine and lagoon habitats.

Juvenile steelhead rescue will be limited to instances where, in the opinion of the Department, habitat conditions are temporarily inadequate and will not be used to mitigate for adverse effects caused by existing water developments or other projects, except where already approved in an accepted mitigation plan. Juvenile steelhead rescue will not be considered as mitigation for proposed water development or other projects. The Department shall strive to improve habitat conditions, alleviate threats, and renegotiate mitigation requirements at appropriate opportunities to eliminate the need for fish rescue operations.

Maintaining genetic variability is as important to the health of wild stocks as is maintaining habitat. Release of juvenile fish raised at artificial production facilities will be governed by the Department's Salmon and Steelhead Stock Management Policy. Arttficial production, rearing, and stocking programs shall be managed so as to produce minimal interference with natural Salmonid stocks.

Artificial production of steelhead will not be considered appropriate mitigation for proposed water projects. Trap-and-truck operations, because of their history of failure to fully mitigate for loss of habitat, will not be considered as mitigation for proposed water projects, except where already approved. For existing the ocean by the construction of barriers but remain genetically similar to the anadromous forms (see page 93).

- **To maintain the genetic purity of remnant native rainbow trout populations, DFG will not plant resident trout in streams where identified populations of native coastal rainbow trout exist.**

MITIGATION

In areas where steelhead coexist with chinook salmon populations, mitigation is usually based on the more economically important salmon populations, with the idea that measures implemented to protect salmon will protect steelhead also. For the most part this is true, but there are two principal differences in life history between chinook salmon and steelhead that can lead to inadequate measures to protect steelhead populations.

Rearing. Juvenile steelhead usually rear from one to three years in the freshwater environment, whereas most juvenile chinook salmon rear for a period of just a few months. If a dam operator is only required to maintain adequate downstream temperatures and flows until most chinook salmon smolts have emigrated (usually by June for fall-run chinook), then habitat conditions can rapidly become intolerable for steelhead juveniles during the summer and fall periods. To maintain steelhead populations, favorable conditions must be maintained year-round.

Spawning and Rearing **Areas.** Steelhead, for the most part, are headwater spawners, because juveniles need to rear in cool, well oxygenated water for at least one year. When a migration barrier is placed in the lower elevations of a stream, adults are relegated to spawning in the lower reaches. Inadequate rearing conditions in the lower reaches result in severe declines of steelhead populations, even though chinook salmon populations may be able to persist because of their shorter rearing requirements.

RESEARCH AND ASSESSMENT NEEDS

CURRENT RESEARCH, MONITORING, AND ASSESSMENT

In response to pervasive large-scale aquatic habitat degradation in California, much of DFG's fishery management efforts have been directed towards habitat restoration, population monitoring, and environmental document review. Present research and monitoring activities are mostly directed towards chinook salmon stock assessment in response to the dramatic declines of the north coast fisheries and Central Valley salmon stocks. Relatively little research has been focused on steelhead; consequently, we have little up-to-date information about the majority of our steelhead stocks.

Assessing population status and environmental impacts is unquestionably of primary importance. However, basic life history and other biological information is necessary to understand the nature and characteristics of a stock so that appropriate management and response to adverse actions can be undertaken. Often, so little is known about a particular steelhead stock in an impacted or soon-to-be impacted system that responses must be based on the characteristics of other, more well-known stocks. Much of what is believed to be true of southern steelhead, for example, is based on general life history characteristics of more northerly winter steelhead stocks. For this reason, basic research into life history, distribution, habitat usage, age and growth, genetics, and harvest impacts should be undertaken for each stock.

Most of the research currently being done is centered on north coast steelhead stocks, mostly on the Klamath-Trinity system. Most information is collected incidently through salmon research programs, but there are a few ongoing studies dedicated exclusively to steelhead. DFG's Natural Stocks Assessment Project has been monitoring steelhead for the past several years, concentrating on life history, distribution, run size, and angler harvest in the South Fork Trinity River (Wilson and Mills 1992) and assessing the contribution of artificial production to escapement and harvest in the Trinity River system (Aguilar 1992). Research on genetics include Hodges et al. (1989) analysis of genetic variations of South Fork Trinity River steelhead and genetic analysis of Klamath and Smith river steelhead by the National Marine Fisheries Service (NMFS) as part of their Illinois River winter steelhead status review (Busby et al. 1993). Other recent research activities on the north coast include: investigations in the utilization of habitat types by naturally produced steelhead juveniles in the South Fork Trinity River basin (Glaze et al. 1991); ongoing monitoring of established steelhead and coho salmon index streams; development of a restoration protocol for Trinity River steelhead; and an unpublished, intensive study of Klamath River steelhead population size, distribution, run timing, and harvest conducted from 1977- 1983.

Considerably less research effort has been expended on the central and south coasts and the Central Valley. Current studies are focused primarily on assessment of steelhead population status and habitat. On the central coast south of San Francisco Bay, studies have been conducted on water quality in small lagoons and estuaries, and the importance of these habitats to steelhead rearing (Smith 1990). Recent steelhead research efforts on the central and south coasts include: an ongoing assessment of steelhead populations in the southern portion of DFG's Region 3 (San Mateo, Santa Cruz, Monterey, and San Luis Obispo counties); an investigation into population regulation, life history selection, and habitat use by juvenile steelhead in the Big Sur River; a historical account and status review of southern steelhead populations (Titus et al. in press); a description of historic and current distribution of steelhead and resident rainbow trout (Swift et al. 1993); habitat assessment and research into micro-habitat distribution of steelhead/rainbow trout on Los Padres National Forest streams by the U.S. Forest Service; and determination of genetic profiles of southern steelhead/coastal rainbow trout (Nielsen 1994; Nielsen et al. in press).

In the Central Valley, fish counters were recently installed to monitor spawning escapement on Mill and Deer creeks. Run size of Sacramento River steelhead passing the Red Bluff Diversion Dam continues to be assessed by ladder counts.

In response to the petition to list steelhead populations of Idaho, Washington, Oregon, and California under the Endangered Species Act (ESA), NMFS has undertaken a status review of the steelhead populations in these four states. As part of this review, they are conducting a cursory genetic analysis of California's steelhead stocks south of the Klamath River.

RECOMMENDED FUTURE RESEARCH

Considerable attention has been focused recently on identification of Evolutionary Significant Units (ESU's) within anadromous fish species, for purposes of defining a "species" under the ESA. A population, or group of populations, is considered to be an ESU (and hence a "species" as defined by the ESA) if it is mostly reproductively isolated from conspecific populations and it represents an important component in the evolutionary legacy of the species (Waples 1991). "Evolutionary legacy" is the term used to describe the uniqueness of a population and its importance to the species as a whole. It is based upon genetical distinctness, uniqueness of habitat, unique adaptations to the local environment, and consequences of extirpation (Waples 199 1).

For this reason, investigations into life history, behavior, straying rates, and genetic profiles of native steelhead populations are needed. Determination of ESU's is not only important for ESA purposes, but also in determining management needs and actions. Investigations into life history and genetic characteristics are needed for the following populations of native steelhead: southern steelhead south of Pt. Conception; southern steelhead north of Pt. Conception; steelhead runs of Deer, Mill, and Antelope creeks and other Sacramento River tributaries; and steelhead populations in the Eel river basin. Also, genetic profiles of rainbow trout populations in isolated headwaters of streams in Los Angeles, Orange, and San Diego counties are needed to determine the relationship between these fish and southern steelhead populations.

DNA and allozyme analysis indicate that sympatric populations of summer and winter steelhead are more closely related to each other than they are to summer or winter steelhead of other drainages (see page 22). More studies are needed to elucidate the degree of genetic interchange between these two life history forms occupying the same drainages so that adequate management strategies can be applied. Questions that need to be answered include:

- What are the mechanisms and degree of isolation, and the extent of gene flow between the two life history types?

- Where do California summer steelhead populations spawn? Is it near their summer holding areas or do they migrate to more suitable areas?

- Are the life history types interchangeable? Can progeny of winter steelhead adopt a summer steelhead life history strategy?

Another area of research that has important management implications is the relationship between steelhead and resident rainbow trout forms, specifically:

- Do isolation mechanisms other than spatial exist between steelhead and resident forms? If so, what are they?

  Can anadromous progeny arise from resident parents? If so, what is the importance of this behavioral plasticity to the persistence of steelhead in those environments where isolation of headwaters due to drought is a natural occurrence?

Investigations into artificial production and anadromous fish culture include:

  Examination of physiological indicators of smolting to determine optimal release time.

Determination of the best release location for steelhead raised at DFG hatcheries.

- Analysis of the contribution of artificially-produced fish to spawning escapement and harvest.

- An examination of the rate and degree of introgression of hatchery stocks into sympatric wild stock gene pools and resultant impacts on individual fitness in wild stocks.

Other areas of needed research include:

Investigations of latitudinal differences in thermal tolerances of steelhead populations to determine if populations have adapted to local water temperature conditions.

Analysis and comparison of various methods to differentiate ocean life history from freshwater life history.

A historical review of steelhead literature in agency files for the north coast and Central Valley, similar to that done by Titus et al. (in press) for the south coast.

Investigations of the effects of marine mammal predation on steelhead stocks.

Evaluation of angling regulations and angler harvest to determine if harvest of juvenile steelhead is impacting steelhead populations on heavily fished streams.

Determination of stream flow requirements for steelhead on individual streams.

Information on population size, distribution, run timing, and harvest of Klamath River steelhead that was collected from 1977- 1983 by DFG should be published. This investigation is the only comprehensive steelhead study spanning several years that has been undertaken in California since Shapovalov and Taft's research on Waddell and Scott creeks in the 1930's and 40's and Hallock et al's study of Sacramento River steelhead in the 1950's. This information is extremely valuable and should be made available as soon as possible. Also, a description of age, growth, and life history of Klamath River steelhead from scale analyses (Hopelain 1987) is in the form of a complete draft, but needs to be finalized and published.

MONITORING AND ASSESSMENT NEEDS

In the north coast area of DFG's Region 5 (Santa Barbara, Ventura, and Los Angeles counties), the District Fisheries Biologist is responsible for management of aquatic resources, which includes steelhead population assessment. Although the majority of the duties of this position involves southern steelhead issues, most activities address habitat protection and management issues, consequently little population monitoring and assessment is done by DFG. Given the precarious nature of these populations and the likelihood that they will be listed under the Endangered Species Act, more extensive assessment is needed. A steelhead monitoring and assessment position needs to be established for this area. A possible alternative would be to expand the area of responsibility for the DFG Region 3 salmon and steelhead biologist so that it includes Santa Barbara, Ventura, and Los Angeles counties.

Because steelhead management attention may be shifted to the severely depleted stocks of the south coast and Central Valley, there is a danger that severe declines in the more abundant populations of the north coast may go unattended. Continuation of steelhead stream index monitoring is necessary to ensure that the health of steelhead populations of the north coast is monitored.

The Trout and Steelhead Conservation and Management Planning Act of 1979 provides much of the direction for DFG's Wild Trout Program and wild trout population monitoring. However, the great majority of effort of the Wild Trout Program is on resident wild trout populations. A greater involvement of Wild Trout Project and regional wild trout biologists in steelhead issues is necessary to adequately monitor important steelhead populations such as those of the upper Sacramento River tributaries, the Yuba and possibly Stanislaus rivers, and coastal streams of Mendocino, Sonoma, and Marin counties.

FUNDING RESOURCES FOR RESTORATION

There are several potential sources that provide funds for agency and public steelhead restoration programs. These include: DFG-Administered funds; Wildlife Conservation Board (Board) funds; and funding from other agency sources. Only one fund can be used solely for steelhead restoration, the others are also available for other specified uses. The amount of funds available from each source varies from year-to-year.

DFG-ADMINISTERED FUNDS

There are a number of funds that are administered through DFG's Fishery Restoration Grants Program. These include: Proposition 99, Proposition 70, the Steelhead Trout Catch Report-Restoration Card funds, the Bosco-Keene Renewable Resources Investment Fund (RRIF), the Central Valley Project Improvement Act (Public Law 102~575), and the Fisheries Restoration Account.

Proposition 99. The Public Resources Account of the Cigarette and Tobacco Products Surtax Fund (Proposition 99), provides funds for fish habitat restoration. The initiative provided 5 % of the Fund revenues for the Public Resources Account for restoration of fish, wildlife, and habitat. Because of legal constraints, no Proposition 99 funds are available for fish rearing activities. Proposition 99 funds are directed toward habitat restoration projects only, based on the wording of Revenue and Taxation Code Section 30 122(b)(5), which governs expenditure of these funds:

> §30122(b)(5) "The Public Resources Account, which shall only be available for appropriation in equal amounts for both of the following:
>
> (A) Programs to protect, restore, enhance, or maintain fish, waterfowl, and wildlife habitat on an equally funded basis.
>
> (B) Programs to enhance state and local park and recreation resources. "

There may be funds available for steelhead from Proposition 99, but funding for the Inland Fisheries Division from this source has been steadily declining.

California Wildlife, Coastal, and Park Land Conservation Fund of 1988 (Proposition 70). This initiative, approved by California voters in 1988, provided $17 million to DFG. A total of $6 million of this fund is to be used for restoration of wild trout and native steelhead resources, specifically:

- restore and enhance wild trout and native steelhead habitat.

- design, develop, and construct anexperimental propagation facility for wild trout and native steelhead.

- acquire critical habitat important for the perpetuation of wild trout and native steelhead.

- provide public access to wild trout and native steelhead waters.

Most or all of the $6 million was earmarked for the design and construction of the experimental wild trout hatchery. Some DFG biologists questioned the need for a large hatchery and believed that this money could be better used to acquire or improve critical habitat (CDFG 1993a). Currently, the money is being used primarily for habitat acquisition and projects, and secondarily, for the construction and operation of a less expensive, smaller-scale, portable, wild trout and steelhead hatchery facility (CDFG 1993a).

One concept is to have a portable egg taking and rearing facility mounted on a trailer that would be temporarily located at a project site (CDFG 1993a). The design would be similar in concept to the portable fish tagging trailers that DFG currently utilizes,. except that the main trailer would house hatching jars, swim-up tanks, other fish culture equipment and appurtenant equipment. Portable tanks would be used to rear the number of fingerlings needed for any specific project.

Recommendations

- ► **The highest priority for the use of Proposition 70 money should be for habitat acquisition and restoration projects.**

- ► **Secondarily, Proposition 70 money should be used to build small, portable hatchery/rearing facilities which could better meet the needs of restoring steelhead to streams where spawning and rearing habitat is inaccessible or limited, such as in the Central Valley.**

Steelhead Trout Catch Report-Restoration Card. Funds generated from report card sales are for steelhead restoration and research only. The enacting legislation (AB 2187, implemented January 1, 1993) states that DFG can only use revenue from the sale of steelhead report cards to monitor, restore and enhance California's steelhead trout resources and to administer the card program.

Proposals for work in the area of steelhead habitat restoration, cooperative steelhead rearing, and public education will be considered annually for funding through the DFG's Fishery Restoration Grants Program. Approximately one-half to two-thirds of this dedicated fund (this will vary with the number of cards sold) may be available annually for steelhead restoration work. Top priority for funding will be given to projects directed at restoring steelhead populations primarily through habitat restoration. Temporary steelhead rearing projects must be operated in conjunction with specific steelhead habitat restoration projects or for the prevention of native stock extirpation.

Proposals will be evaluated by DFG and the California Advisory Committee on Salmon and Steelhead Trout. The proposals will be evaluated according to their adherence to steelhead management objectives as identified in this plan.

Bosco-Keene Renewable Resources Investment Fund (RRIF). Pursuant to Public Resources Code Section 34000, these funds may be used for salmon and steelhead hatchery expansion and fish habitat improvement. The amount of funding made available to DFG varies from year to year.

Title 34 **of Public Law 102-575.** Better known as the "Central Valley Project Improvement Act", this legislation was passed by Congress and signed into law in 1992. It established fish and wildlife protection and restoration as an overall CVP purpose, placed limitations on water contracting, reserved 800,000 acre feet of CVP yield for fish and wildlife restoration, and established a restoration fund of 50 million dollars annually. Federal or State funding (currently undetermined amount) may be made available for steelhead restoration in the Central Valley as this legislation is implemented.

Fisheries Restoration Account. The Keene-Nielsen Fisheries Restoration Act of 1985 created this account. Approximately $12 million was appropriated by the legislation to the account between 1985 and 1987. The Act was reworded through 1990 legislation, which closely tied expenditures from it to projects called for under the Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988. The Legislation provided no funding to the account, however. Appropriations to the account are described in Section 11 SO of the annual State Budget Act.

WILDLIFE CONSERVATION BOARD FUNDING

The Wildlife Conservation Law of 1947 (FGC Sections 1300 et seq.), authorizes the Board to make grants to public agencies and nonprofit groups for fish and wildlife habitat restoration. The Board has legal responsibility for disbursement of a variety of funds.

Wildlife Restoration Fund. This fund receives $750,000 annually from horse racing revenues. The funds are directed to implementation of the Wildlife Conservation Law of 1947.

California Riparian Habitat Conservation Program. The California Riparian Habitat Conservation Act (FGC Sections 1385 et seq.) established this program to protect, preserve, and restore riparian habitat throughout the State through acquisition of interests and rights in land and waters.

California Wildlife Protection Act of 1990. This ballot measure, approved in 1990, created the Habitat Conservation Fund and provided for an annual appropriation of $30 million to it from the General Fund. The General Fund obligation can be reduced on a dollar-for-dollar basis by transfers to the Habitat Conservation fund from other specified funding sources, including, among others, the Public Resources Account, Cigarette and Tobacco Products Surtax fund and the California Environmental License Plate Fund. The Board is responsible for administering annual appropriations to the Habitat Conservation Fund of up to $11.5 million. Pursuant to FGC section 2786(e), funds may be used for acquisition, restoration, or enhancement of aquatic habitat for spawning and rearing of anadromous salmonids and trout resources.

OTHER AGENCY SOURCES

Cal Trans Environmental Enhancement and Mitigation Program. Funds are available to enhance or mitigate fisheries resources impacted by highway projects. The program provides grants to local, state and federal agencies and nonprofit entities to mitigate the environmental impact of modified or new public transportation facilities. The Environmental Enhancement and Mitigation Program was established by the enactment of the Transportation Blueprint Legislation of 1989 (AB 421, Katz). This legislation provided for an annual allocation of $10 million that will be distributed through the Resources Agency to FY 2000-200 1.

Grants for individual projects are generally limited to $500,000 each, but may be larger if certain criteria are met. Categories of environmental enhancement and mitigation projects eligible for funding include the acquisition, restoration or enhancement of resource lands to mitigate the loss of, or the detriment to, resource lands lying within or near the right-of-way acquired for proposed transportation improvements. Resource lands include natural areas, wetlands, forests, woodlands, meadows, *streams*, or other areas containing fish or wildlife habitat.

Environmental Protection Agency (EPA) Wetlands Protection Grants. The EPA Wetlands program, roughly $500,000 allocated annually for California, is coordinated by the Resources Agency and is available to all interested state departments. This funding source may be available for riparian assessment, enhancement and restoration.

EPA Near Coastal Waters Program (NCW). The NCW Program was established by the EPA in 1986, to integrate and address coastal water issues. Through the NCW Program, EPA is encouraging coastal managers to use existing resources and regulatory authority, and innovative management techniques, to bring about measurable environmental improvements.

The intended use of these funds is to implement projects in specific coastal watersheds and offshore waters of California, Hawaii and the Pacific Islands, that protect and restore water quality and habitat. The selected California coastal watersheds and their associated offshore waters for FY 1993-94 are: San Diego Bay, Santa Monica Bay, Morro Bay, Elkhorn Slough, San Francisco Bay (up to the Carquinez Bridge), and the north coast watersheds.

Bring Back The Natives. This is a new national effort by the Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and the National Fish and Wildlife Foundation to improve the status of native aquatic species on public lands through riparian area rehabilitation, watershed restoration, and species reintroduction. Preserving the biodiversity and ecological integrity of unique areas is an essential component of the restoration strategy.

The Fish and Wildlife Foundation contributes money to the program in the form of a challenge grant to USFS and BLM. To receive funding for individual projects, the project proponent must secure an equal amount of funds from non-federal sources (e.g. private, corporate, or state sources). In addition, both BLM and USFS can contribute money to the projects. Thirty-four *Bring Back the Natives* projects received funding in 1993: the Fish and Wildlife Foundation provided a total of $400,000 to projects, BLM and USFS contributed over $800,000, and approximately $400,000 was provided from non-federal contributions.

MANAGEMENT OBJECTIVES

For purposes of this plan, California steelhead populations are grouped into three management areas: North Coast (north of San Francisco Bay), Central Valley, and South Coast (south of San Francisco Bay) (Figs. 3, 5, and 8). These areas may not necessarily reflect biological domains or infer stock relationships, but they do contain steelhead stocks with similar life histories and characteristics. Also, stocks within the three areas are subject to similar impacts, hence they have similar management objectives.

It is beyond the scope of this plan to address all issues and problems within the management areas. The specific issues and problems that are discussed in this section are of a high priority, and implementing the proposed solutions will contribute significantly toward conservation and restoration of stocks within the management areas. The recommended management objectives specified in this section are relatively urgent and, in some cases, necessary to prevent the extirpation of specific wild stocks. All problems and issues have not been identified, however, so this section is not meant to be a complete prescription of needed actions and solutions.

Central Valley

INTRODUCTION

The natural hydrography of the Central Valley has been greatly altered by agricultural and municipal water development (Fig. 5). Steelhead populations have been most severely affected by dams blocking access to headwaters of the main stem Sacramento and San Joaquin rivers and all the major tributaries. Inadequate flows due to excessive diversions, elevated water temperatures, and unscreened or poorly screened diversions have also contributed to the decline.

Declines in naturally spawning steelhead stocks have been greater than that of fall-run chinook salmon in the Central Valley because chinook salmon can utilize low elevation spawning habitats. Unlike steelhead, juvenile salmon require only a few months rearing time in fresh water. Thus, inhospitable summer conditions in low elevation reaches below dams, which can be very hostile for rearing steelhead, have little effect on fall-run chinook salmon because juveniles have already emigrated to the ocean. Central Valley spring-run chinook salmon stocks, which, under natural conditions, have a longer freshwater rearing requirement, and have life history characteristics similar to steelhead, have experienced declines as great in magnitude as wild steelhead.

As a direct result of dam construction, most of the headwaters in the system are now inaccessible to steelhead and the amount of spawning and rearing habitat available is negligible compared to historical levels. Minor Sacramento River tributaries which do not have impassable dams, such as Mill and Deer creeks, contain the last good spawning and rearing habitat available to steelhead in the Central Valley. Although the number of steelhead that spawn in the main stem is not known, it is probably quite low. Elimination of access to headwaters has, for the most part, rendered the Central Valley system unsuitable for natural reproduction of steelhead.

Development of increased water supplies has been the responsibility of the federal Central Valley Project (CVP) and the State Water Project (SWP), the two major water developers in the Central Valley. Major facilities of the two projects include six reservoirs with capacities greater than 1 .O million acre-feet, several thousand miles of aqueducts and canals, and two major pumping plants (which have a combined capacity of nearly 15,000 cfs) located in the Sacramento-San Joaquin delta. These massive water projects have greatly enhanced agricultural productivity and domestic water supply but have exacted a heavy cost on aquatic resources and industries which depend on them. Serious efforts by the water agencies to reverse the decline in fisheries caused by the CVP and SWP have only been undertaken in the past few years.

There is no shortage of planning documents for restoring Central Valley anadromous fisheries. Most were developed because of low returns of chinook salmon, hence, their focus has been on salmon recovery, usually with the assumption that efforts to restore salmon would also benefit steelhead. This is, for the most part, a valid assumption, but adequate habitat conditions must be maintained year-round if steelhead are to benefit.

Perhaps the biggest problem with focusing on salmon is that it has resulted in inattention and lack of effort to assess the status of steelhead populations, particularly native populations. It is quite possible that naturally spawning steelhead populations in upper Sacramento tributaries have declined to levels less than that of winter-run chinook salmon, a state and federal endangered species, and spring-run chinook salmon, a population of concern. Hallock (1989) attributes this dearth of information on Central Valley steelhead stocks partly to the low priority steelhead are given by management agencies. He cites as an example, cancellation in the late 1950's of the only comprehensive steelhead research program undertaken in the Sacramento River system. Since that time, steelhead studies have been infrequent and narrow in scope.

Planning efforts to restore the anadromous fish resources in the Central Valley include:

> *Upper Sacramento River Fisheries and Riparian Habitat Management Plan* (USRFRHAC 1989). This plan, also known as the " 1086 Plan" after Senate Bill 1086, was enacted into state law in 1986. It mandated the development of a management plan which identified needed actions with specified time frames, estimated cost and benefits, and proposed funding sources.
>
> *Central Valley Salmon and Steelhead Restoration and Enhancement Plan.* (CDFG 1990). This plan outlined DFG's restoration and enhancement goals for salmon and steelhead in the Sacramento and San Joaquin river systems and provides management direction.
>
> *Central Valley Project Improvement Act (PL 102-575).* This legislation was passed by Congress and signed into law in 1992. It established fish and wildlife protection and restoration as an overall CVP purpose, placed limitations on water contracting, reserved 800,000 acre feet of CVP yield for fish and wildlife restoration, and established a restoration fund of $50 million annually.

- *Restoring Central Valley Stream: A Plan for Action* (Reynolds et al. 1993). This plan identifies specific actions, priorities, and costs for anadromous fish restoration in the upper and lower Sacramento and San Joaquin tributaries.

In addition to these documents, DFG has published management plans for the lower Yuba (CDFG 1991a) and the lower Mokelumne (CDFG 1991b) rivers, and a steelhead restoration plan for the lower American River (McEwan and Nelson 199 1).

- **Management focus for Central Valley steelhead will be to recover native and wild populations and to restore hatchery maintained runs.** Implementation of the actions identified in the plans mentioned above, and other actions discussed in this section, will assist greatly in achieving these goals.

MAINSTEM SACRAMENTO RIVER

The Sacramento River below Keswick Dam is beset with many of the ecological problems associated with highly regulated rivers. This river is important not only because it provides much of the State's water supply (35 %), but also for its contribution to the State's sport and commercial salmon industries. These two potentially conflicting functions lie at the heart of California's present water controversy.

Impacts

Impacts to production and survival of steelhead and other anadromous fish in the main stem Sacramento River result from water diversions and associated structures; high water temperatures; pollution; channelization, flood control, and bank protection projects; and water export operations in the Sacramento-San Joaquin Delta.

Diversions. Three large-scale diversions, the Glenn-Colusa Irrigation District (GCID) , Anderson-Cottonwood Irrigation District (ACID), and the Tehama-Colusa and Corning canals at the Red Bluff Diversion Dam (RBDD), can divert 3,000, 400, and 3,000 cfs, respectively. The mechanical drum screens on the GCID diversion are not effective and are responsible for the entrainment of large numbers of salmonids. The ACID diversion dam creates fish passage problems and requires a substantial reduction in releases from Keswick Reservoir to adjust the dam flashboards, which results in dewatering of redds, stranding of juveniles, and high water temperatures. Despite the presence of three fishways, RBDD continues to hinder upstream migration. Also, squawfish predation on juvenile salmonids is high at this facility.

In addition to the problems created by these large scale diversions, there are an estimated 300 smaller unscreened diversions on the Sacramento River between Keswick and the Delta.

High Water Temperatures. Elevated water temperatures in the upper Sacramento River has been a major factor in the decline of winter-run chinook salmon and may affect juvenile steelhead rearing in the river. High water temperatures result mostly from inadequate carryover storage in Shasta and other reservoirs.

Agricultural drainage is generally several degrees higher in temperature and can result in elevated temperatures in the lower river. The Colusa Basin Drain, which captures agricultural runoff in Glenn, Colusa, and Yolo counties, discharges into the lower Sacramento River and is responsible for causing high temperatures.

Pollution. Spring Creek Dam was built to capture pollution-laden runoff from the Iron Mountain Mine complex so that lethal effects of the pollutants could be attenuated by controlled releases from the reservoir. Spring Creek Reservoir has insufficient capacity and uncontrolled spills have resulted in documented fish kills in the 1960's and 70's (USRFRHAC 1989). Greater releases from Shasta Reservoir are required to dilute the uncontrolled releases, which diminish storage needed to maintain adequate flows and water temperatures later in the year.

Other pollutants include: effluent from wastewater treatment plants; chemical discharges, principally dioxin and furans, from pulp and paper mills; and biocides from agricultural runoff. Agricultural drain water can contribute up to 30% of the total inflow into the Sacramento River during the low flow period of a dry year (Sacramento River Information Center 1993).

Chaxmelization, Flood Control, and Bank Protection Projects. Bank stabilization projects generally entail removal of riparian vegetation and loss of habitat through replacement of natural bank with large rock riprap. This has led to extensive removal of large tracts of riparian forest, which results in reduced shading and reduction of instream habitat and organic inputs. Central Valley riparian forests have been reduced to about one percent of the original pre-Gold Rush acreage (Abel1 1989).

Water Export Operations. The Harvey 0. Banks pumping plant (SWP) and the Tracy Pumping Plant (CVP) have a combined maximum pumping capacity of 14,900 cfs, or nearly 30,000 acre-feet per day (Fig. 13). Fish screening facilities are located on the intakes to the pumping plants, but juvenile fish of many species are lost through the outdated louver screens. In addition, large numbers are lost through handling and trucking, and through

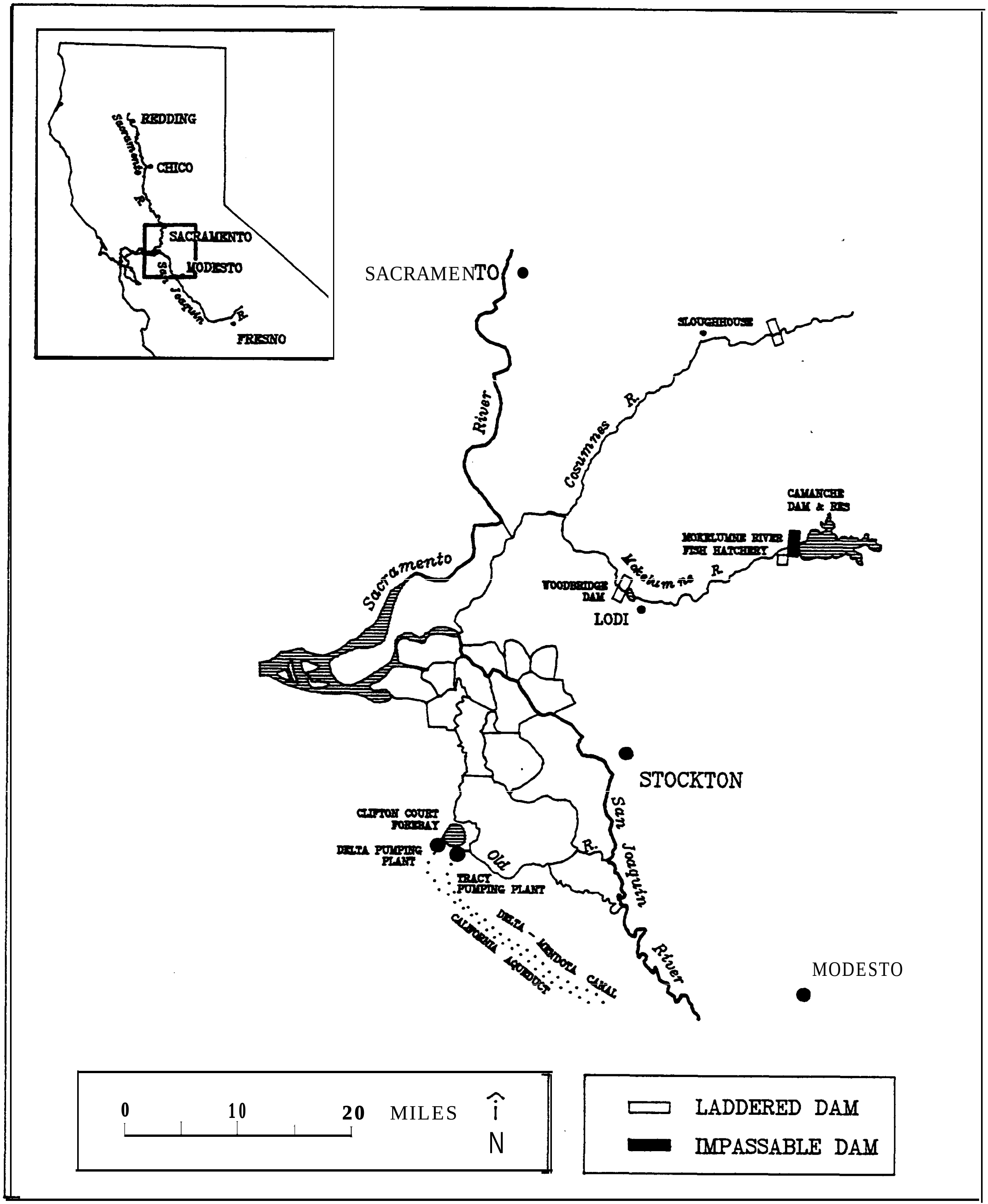


Figure **13.** Lower reaches of the Sacramento and San Joaquin rivers and principal tributaries.

predation by striped bass and other piscivores in the diverted flow through the Delta, at the facilities, or in Clifton Court Forebay. The massive amount of water that is diverted and the resultant reduced outflows to San Francisco Bay has disrupted adult and juvenile Salmonid migration, reduced anadromous fish populations, and changed hydro- and ecological dynamics of the delta and estuary. Water export operations have been identified as the major cause of the decline of salmonids, striped bass, non-game native fishes, and aquatic invertebrates.

The estuary, once an important rearing area for juvenile salmonids, is no longer a safe haven for juvenile rearing. Protective management strategies for Central Valley anadromous fishes now stress the need to pass them through the estuary as quickly as possible to prevent entrainment into the interior or south delta. The effect of the water export pumps on steelhead has not been investigated.

Restoration Measures

The planning documents previously mentioned describe and recommend corrective actions for many of the problems of Central Valley steelhead production and survival. Rectifying these problems will undoubtedly increase survival of migrating adults and juvenile steelhead. The most important of these actions include:

Installation of state-of-the-art fish screens at the GCID diversion.

Correction of fish passage and loss problems at RBDD. A pilot program is underway to determine the effectiveness of screw pumps as an alternative to the present gravity flow diversion. If this is effective, it would eliminate or reduce the need for the dam gates, and would allow unobstructed fish passage.

DFG, DWR, and USBR have launched an aggressive campaign to screen small agricultural diversions. This includes educating farmers on the need for screening, involving them in the decision making process, and providing technical expertise. This program should be accelerated.

Several organizations are attempting to establish carryover storage standards for

Iron Mountain Mine is an Environmental Protection Agency Superfund Site. Measures to clean up this site include diverting the upper Spring Creek tributaries away from the metal sources and reducing groundwater contamination by filling the mine shafts with concrete.

Evaluation of the feasibility of rerouting the Colusa Drain so that it does not discharge directly into the lower Sacramento River.

Mandates to restore the Sacramento-San Joaquin Delta/Estuary and salmon populations, and listing and proposed listing of several species of native fish has encouraged state and federal water agencies to begin considering actions to reverse the decline of the delta and other aquatic ecosystems. This may lead to implementation of measures such as curtailment of water exports during critical times of the year, a decreased frequency of negative flows in the lower San Joaquin River, and greater outflows to San Francisco Bay.

Recommendation

- ► **Identified measures to restore the Sacramento River and estuary should be implemented as soon as possible.**

UPPER SACRAMENTO RIVER TRIBUTARIES

Cow, Battle, Clear, and Cottonwood creeks offer the best opportunities for restoration of native and wild steelhead populations’ in the upper Sacramento River (Fig. 14). These streams have not been surveyed to assess steelhead populations for several years so the status of spawning populations is unknown, although it is assumed to be quite low. Incidental observations of steelhead have been reported in several of these streams.

Cow Creek. This stream still contains adequate habitat, and despite several impediments to migration, steelhead can still access the headwaters.

Battle Creek. Pacific Gas and Electric Company operates the Battle Creek Hydroelectric Project, which consists of two reservoirs, four unscreened diversions, and five powerhouses. Impacts to salmon and steelhead are from inadequate releases below the diversions, entrainment of juveniles, and removal of spawning gravel (USRFRHAC 1989). In addition, Coleman National Fish Hatchery, which is located on lower Battle Creek, does not consistently allow steelhead to access the stream above the hatchery for fear of introducing disease problems to the hatchery fish (Jim Smith, USFWS, pers. comm.).

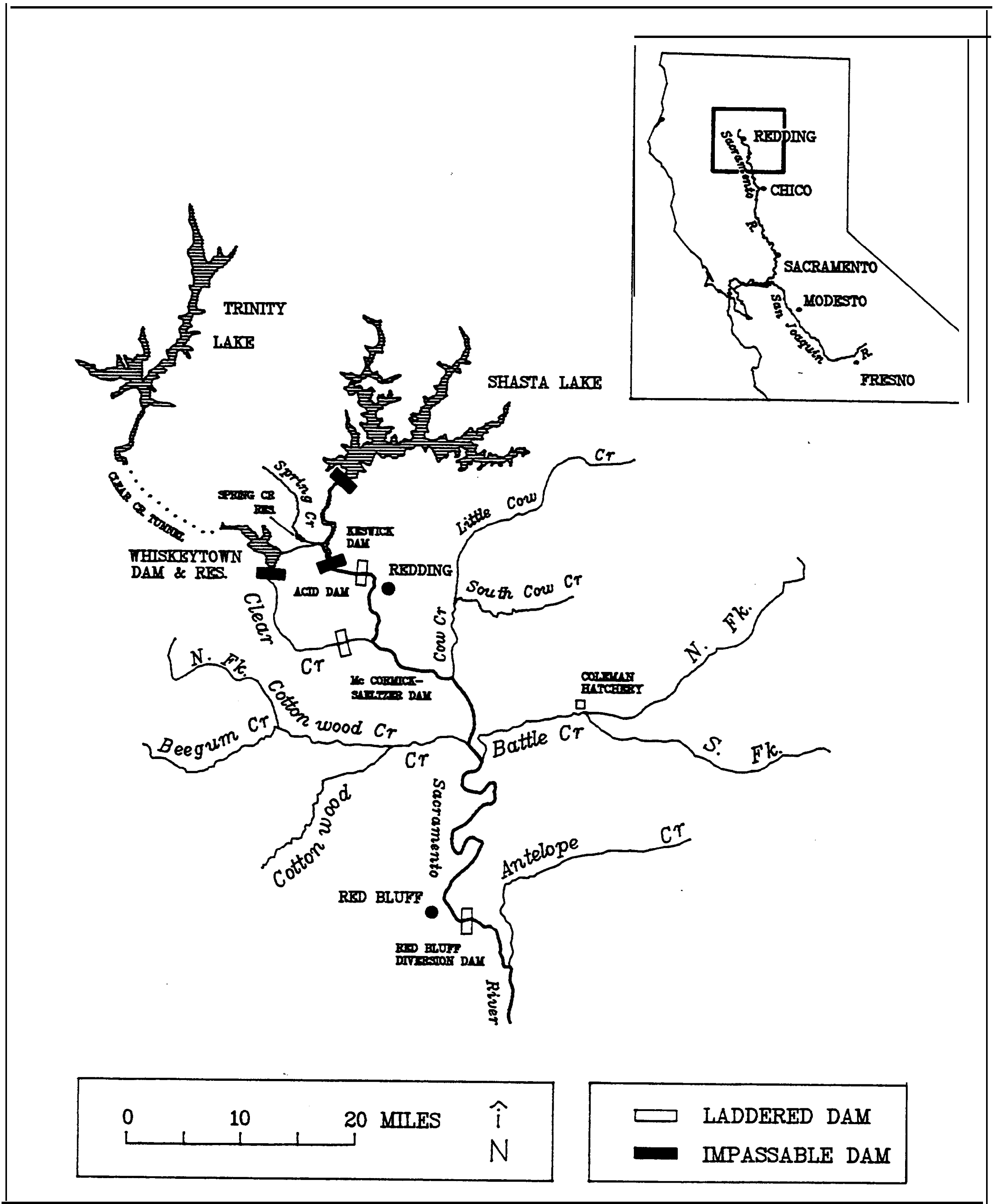


Figure 14. Upper Sacramento River and principal tributaries.

Clear Creek. Since the construction of Whiskeytown Dam in 1963, more than 85 % of the natural flow of Clear Creek has been diverted for power production (USRFRHAC 1989). McCormick-Saeltzer Dam, located approximately halfway between Whiskeytown Dam and the confluence with the Sacramento River, has been a significant barrier to migration of steelhead and salmon. The fishway on the dam has recently been modified to facilitate passage. This should be adequate to allow steelhead to access the cooler water below Whiskeytown Dam, where temperatures are adequate for steelhead rearing (Colleen Harvey, DFG Associate Fishery Biologist, pers. comm.).

Cottonwood Creek. Steelhead habitat in Cottonwood Creek has been severely degraded due to scouring effects of high flows, siltation from timber harvest operations, road building, gravel mining impacts, and loss of riparian vegetation.

Recommendations

- **Minimum bypass requirements at the diversions on the north and south forks of Battle Creek are inadequate. Greater stream flows should be maintained below these diversions.**
  Foregoing power generation will result in less diversion and greater bypass flows. DFG is exploring the option of compensating lost power production with USBR power or funds provided by the Central Valley Project Improvement Act (Dick Daniel, DFG Environmental Services Program Manager, pers. comm.).

- **Steelhead should be allowed to ascend Battle Creek beyond Coleman Hatchery to spawn naturally.**
  Because there are so few steelhead spawning and rearing tributaries remaining in the Central Valley, steelhead should be allowed to access those that are still readily accessible. A water treatment plant is included in long-term rehabilitation plans for Coleman Hatchery which will provide a disease-free water supply for the hatchery despite the presence of steelhead in the upper reaches of Battle Creek. A funding source is needed before construction can begin (Jim Smith, USFWS , pers. comm.).

- **Flow releases from Whiskeytown Reservoir to Clear Creek need to be increased.**
  The 1086 Plan (USRFRHAC 1989) identifies a need to more than double the current releases to provide adequate habitat for salmon and steelhead. Power production would be reduced but the bypassed flows would remain in the Sacramento River system so they would not be lost to CVP irrigation.

- **The few remaining areas of gravel reserves in Clear Creek should be protected through acquisition or regulation.**
  Gravel mining in Clear Creek has been extensive and has resulted in a substantial reduction in gravel available for spawning.

- **Gravel mining on Cottonwood Creek should be monitored and restricted, if necessary, to insure that operations do not adversely impact steelhead.**

MILL, DEER, AND ANTELOPE CREEKS

Mill, Deer and Antelope creeks have the greatest potential for restoring wild steelhead populations in the entire Central Valley system (Fig. 15). These streams have fairly pristine, well-protected, upper reaches with ample spawning and rearing habitat but they suffer from inadequate flows in their lower reaches.

Spring run Chinook Salmon Restoration Efforts. Recently, there has been considerable attention placed on the restoration of spring-run chinook salmon populations in Mill, Deer, and Antelope creeks. The *Spring-run Chinook Salmon Workgroup* has been established to explore measures to recover these populations so that listing under the Endangered Species Act (ESA) does not become necessary. Implementation of restoration measures to restore spring-run chinook will likely benefit steelhead, however, focusing all of the attention on one species can lead to inadequate assessment, management, and recovery efforts for other species. Steelhead need to be included in the recovery process for the following reasons:

There are indications that there are less wild steelhead in these streams than there are spring-run chinook (Harvey 1995).

Steelhead have been petitioned for listing (Oregon Natural Resources Council et al. 1994) and there is a possibility that they will be designated as Endangered or Threatened in the near future.

Focusing on a single species can lead to actions that may unintentionally harm other species, or appropriate actions to improve habitat for other species may not be implemented because there is no direct benefit on the target species.

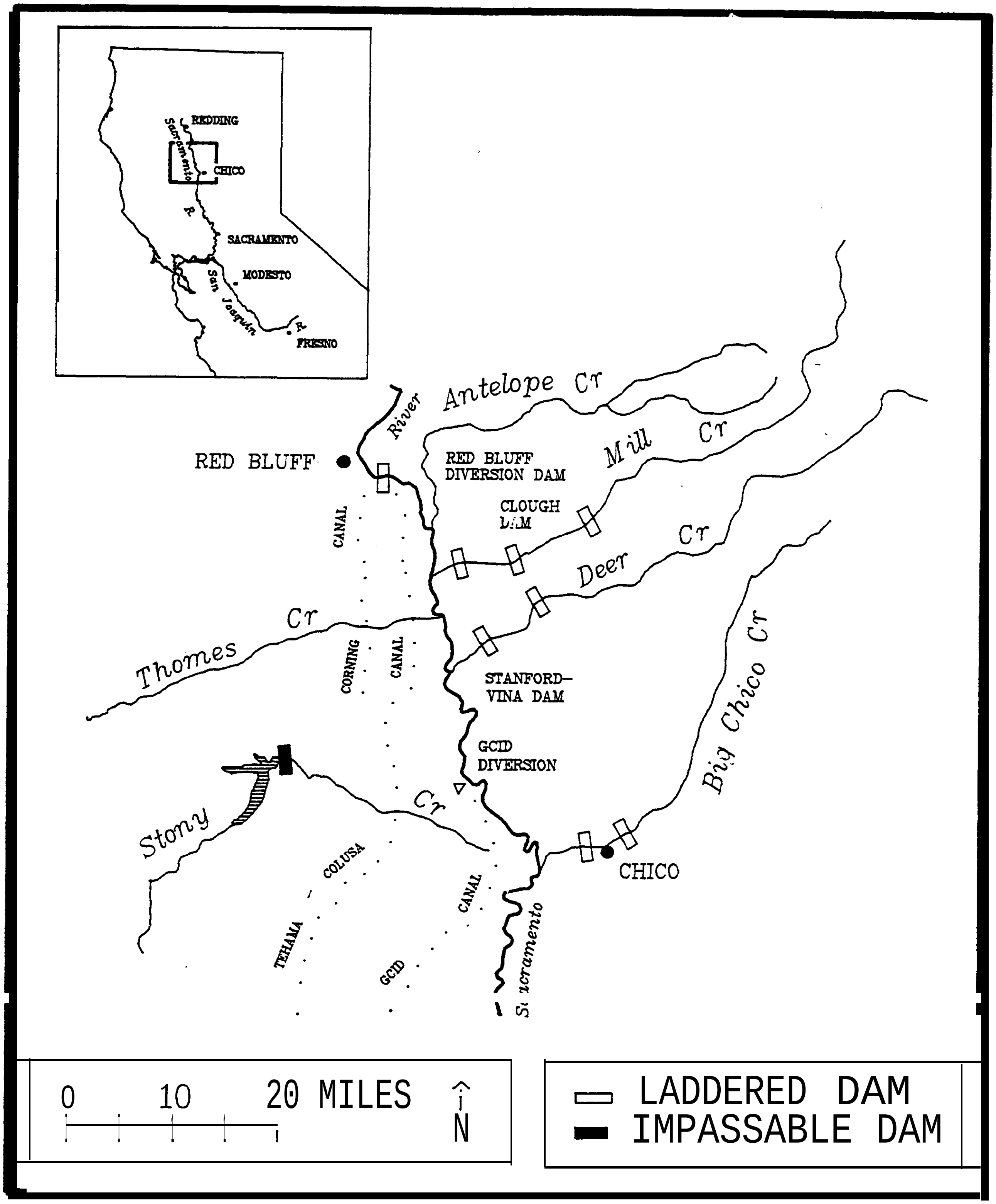


Figure 15. Sacramento River and principal tributaries from Red Bluff to Chico.

Recommendation

- **Agencies and constituent organizations concerned with spring-run chinook salmon restoration on upper Sacramento River tributaries should focus their efforts on restoring all anadromous fish populations, rather than a single species.**
  Steelhead need to be included in recovery planning for anadromous fish habitat in upper Sacramento River tributaries.

Instream

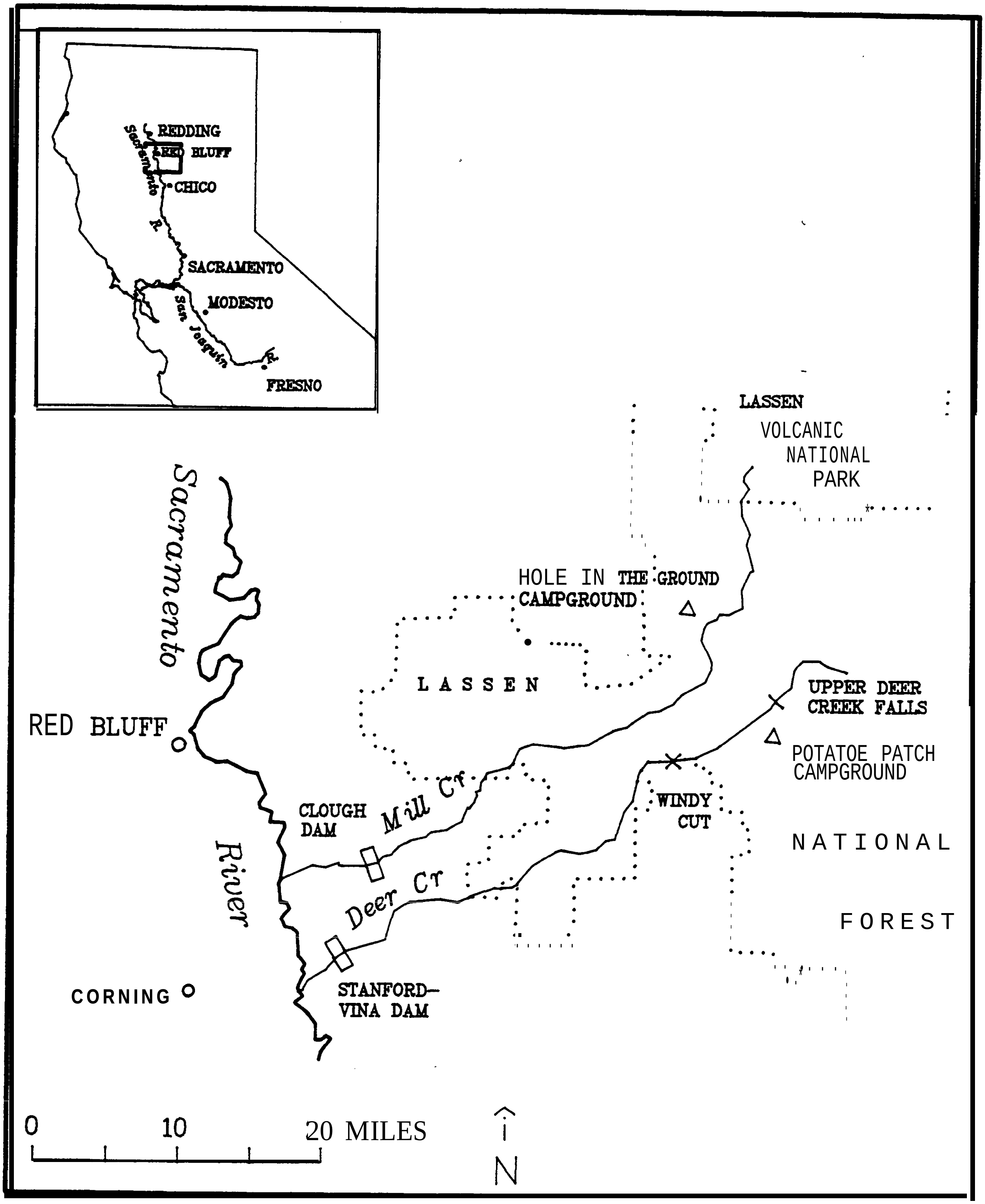


Figure 16. Mill and Deer creeks.

Statement (CDFG 1993b). There is a concern, now that the problems in the lower reaches are being resolved, that the critical holding and spawning habitat in the mid reaches may become impacted by inappropriate forest management. Reasons for the appeal pertaining to anadromous fish are:

- The need for a watershed study of the Mill Creek drainage to identify significant sediment sources and plans to reduce sediment impacts was not addressed.

- The LRMP would allow road building, logging, campground construction, and increased access on presently unroaded areas adjacent to the most important spawning and holding habitat for spring-run chinook salmon on Mill Creek.

- The LRMP does not incorporate protections for 200 foot corridors on Class I, II, and III perennial streams, which would allow significant impacts from logging to occur.

Lassen National Forest has recently come under PACFISH management strategy to restore anadromous fish habitat (see page 67). Because of this, the LRMP may be amended to provide greater long-term protection for anadromous fish habitat on Mill and Deer creeks. The Forest Service is presently managing those portions of Mill and Deer creeks on Lassen National Forest lands as if they were designated Wild or Scenic.

- **DFG supports the inclusion of the above protections in the Lassen National Forest** *Land and Resource Management Plan* **for the Mill and Deer creek watersheds.**

Mill and Deer creeks have been proposed for inclusion in the State and National Wild and Scenic Rivers Acts. Recent legislation required the California Resources Agency to evaluate these two streams for their suitability for Wild, Scenic, or Recreational status. Jones and Stokes Associates, an environmental consulting firm, has recently completed a study which concludes that portions of both streams are suitable for inclusion in the State act. Designation of these streams as Wild or Scenic could provide greater protection for aquatic habitat in these streams. Alternatives designed to afford equal habitat protection are currently being investigated by local watershed groups.

Trout Stocking. Until very recently, DFG planted catchable rainbow trout at Potato Patch Campground on Deer Creek (about two miles downstream from Upper Deer Creek Falls) and at Hole-in-the-Ground Campground on Mill Creek (Fig. 16). These two areas are within the anadromous reaches of these streams and they have good spawning habitat for steelhead and good holding habitat for spring-run chinook (Frank Fisher, DFG Associate Fishery Biologist, pers. comm.).

Policy changes recently adopted by the Fish and Game Commission (FGC) directed DFG to cease stocking of catchable trout in the anadromous portions of these streams. This change was adopted because of possible impacts to steelhead and spring-run chinook salmon from catchable trout planting and intensive angler use. These impacts could result from competition and possible hybridization between residualized rainbow trout and native steelhead, increased harvest on juveniles associated with heavy fishing pressure, and trampling of late spawning steelhead and spring-run chinook salmon redds. Angling and rainbow trout plants are not a major cause of the declines of spring-run chinook salmon and steelhead, but they could impede restoration of the naturally spawning population.

Angling Regulations. Currently, Mill and Deer creeks support popular rainbow trout fisheries. The decline of wild steelhead and spring-run chinook salmon in Mill, Deer and Antelope creeks has necessitated a change in fishery management strategy for these and other upper Sacramento River tributaries, however. DFG is currently managing these streams for anadromous fish and is actively pursuing measures to correct habitat and streamflow problems that have impacted these stocks. The recent regulation changes recommended by DFG and adopted by the FGC conform to DFG's new management direction to restore the salmon and steelhead populations in the anadromous portions of these streams.

Until very recently, regulations on the mid- and upper reaches of Mill, Deer and Antelope creeks allowed angling from the last Saturday in April through November 15. Five rainbow trout over 12 inches could be possessed per day. It is unknown how many adult steelhead were harvested, but the five fish limit could have allowed for a substantial number to be taken. The lower reaches of these streams were closed to angling in 1990 to protect migrating adults, especially because of their vulnerability during low flow conditions.

Compilation of the fish counts from Clough Dam on Mill Creek from the 1953-54 through 1962-63 seasons (Hallock 1989) show that 39.6% of the run passes through the fishway from September 17 through November 18. Assuming that run timing on Deer and Antelope creeks are essentially the same, approximately one-third of the spawning populations of these three streams would have been subjected to a fishery with a five fish daily bag limit. The potential for over-harvest is substantial and could have been a factor in the decline of these populations.

The critically low population levels necessitated a change in angling regulations to prevent any possible harvest of these fish. The new regulations for these streams, which became effective March 1, 1994, include:

> Retention of the present year-round closures on the three streams.
>
> Reduction in daily bag limit to 0 trout from the upstream end of the present closures to: Upper Deer Creek Falls on Deer Creek; the Lassen Volcanic National Park boundary on Mill Creek; and the confluence with the North Fork Antelope Creek on Antelope Creek.

Monitoring. A multi-year monitoring program, funded by Steelhead *Trout Catch Report-Restoration Card* revenues, began in October, 1993. Electronic fish counters were installed on the fishways on Clough Dam on Mill Creek and Stanford-Vina Dam on Deer Creek, and are staffed by scientific aids. This effort will be similar to the spring-run chinook salmon monitoring program that is currently being done on these two streams, but will be broader in scope and will continue through the entire steelhead migration season (September through June).

- **DFG will continue monitoring efforts on Mill and Deer creeks.**

Endangered Species Act Considerations. The Tehama Flyfishers (1992) have expressed a concern regarding the continued existence of native Central Valley steelhead and have considered petitioning the Fish and Game Commission to list these populations under the California Endangered Species Act. Measures to protect the Mill and Deer creek watersheds and restore the steelhead populations are necessary to prevent further declines which will necessitate listing.

BUTTE CREEK

The construction of Pacific Gas and Electric's Butte Creek and Centerville head dams in the foothill reach of Butte Creek eliminated steelhead access to the headwaters of the Butte Meadows basin (Brown 1992). Steelhead are now restricted to the lower reaches of the canyon and tributaries such as Dry Creek. In addition, there are ten diversion dams on the Valley reach of Butte Creek, all of which are known to impede salmon and steelhead migration (Fig. 17). All of these diversions are unscreened. These diversions, and the complexity of water right ownership in lower Butte Creek, result in inadequate flows and blocked passage.

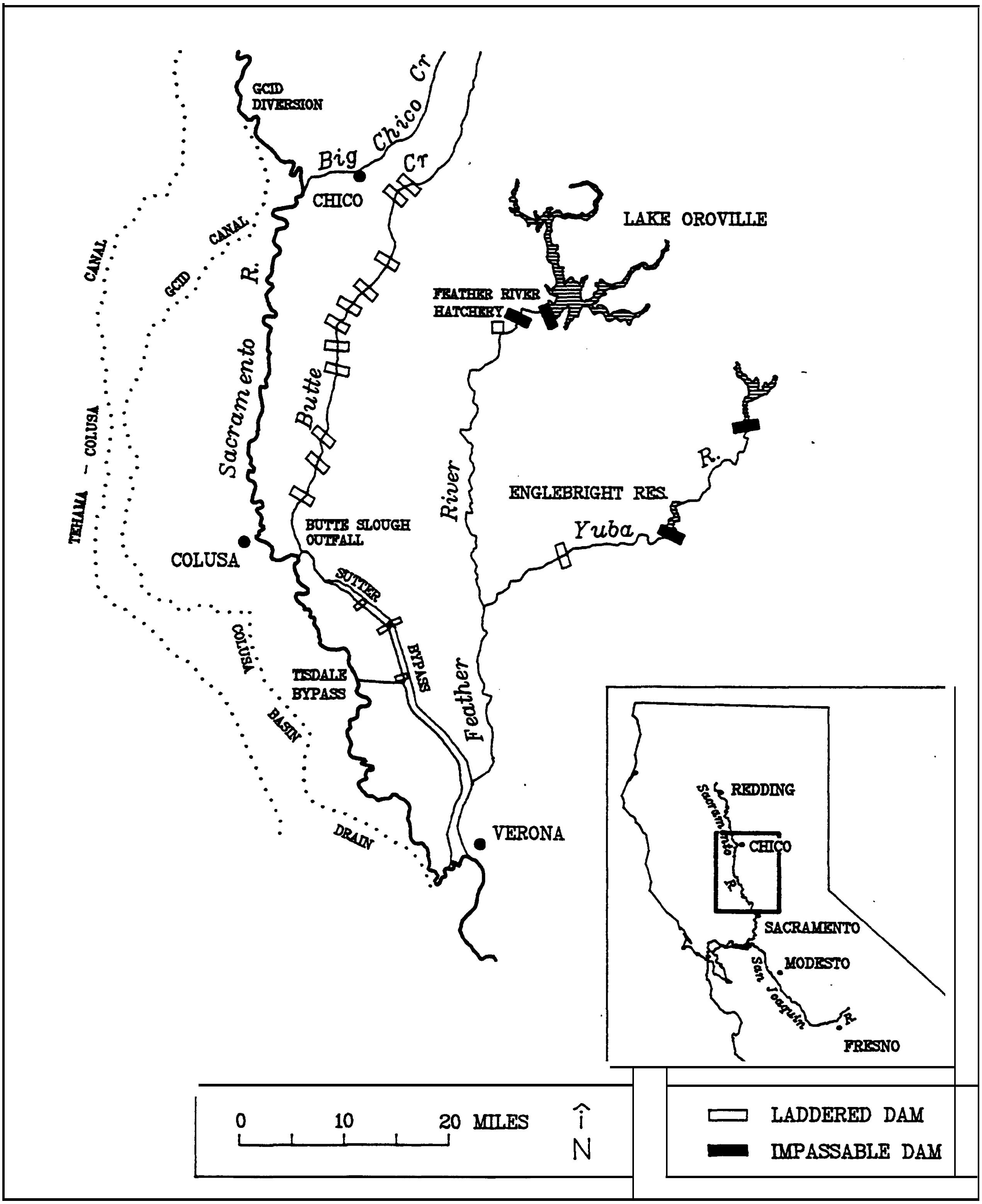


Figure 17. Sacramento River and principal tributaries from Chico to Verona.

Identified actions (USRFRHAC 1989) needed to restore steelhead and salmon in Butte Creek include:

> Assure an adequate water supply for the lower reaches. There are several interconnections between Butte Creek and other systems, such as Thermalito Afterbay via Western Canal. Butte Creek flows could be augmented from these sources during critical low flow periods. Another option would be to establish flow needs for the stream and seek relief through the SWRCB process. Adjudication of the entire system by the SWRCB should be undertaken and Watermaster Service should be provided to assure coordinated operations and sufficient instream flows. A third option would be to purchase surplus water and acquire additional water rights.
>
> Modify or construct adequate fishways and provide adequate screens for diversions.
>
> Correct water temperature and agricultural drain problems.
>
> Implement habitat restoration work in lower Butte Creek, such as sediment control and revegetation of streambanks.

In addition to the above, the Butte Creek and Centerville head dams should be modified to allow passage so that steelhead can access Butte Creek Canyon and the headwaters.

Recommendation

- **The above measures to restore Butte Creek anadromous fish populations should be implemented as soon as possible.**

YUBA RIVER

The Yuba River supports a self-sustaining population of steelhead and is essentially the only wild steelhead fishery remaining in the Central Valley (Fig. 17). This river was annually stocked with 27,270 to 2 17,378 yearling steelhead from Coleman National Fish Hatchery between 1970 to 1979 (CDFG 1991a). It is unknown whether the present stock is of native origin or is derived from the planting of Coleman fish. It is currently managed as a self-sustaining population.

Low flows and elevated water temperatures resulting from water diversions have affected the anadromous populations of the lower Yuba River. DFG has recommended temperatures and flows needed to maintain and restore the anadromous fisheries (CDFG 1991a) and has presented these recommendations to the SWRCB. The SWRCB has not yet made a decision.

In addition to the flow and temperature recommendations, the *Yuba River Fisheries Management Plan* (CDFG 199 la) identifies other needed actions to restore *the* anadromous fisheries:

Providing adequate fish screens for all diversions.

Gravel mining operations should be monitored and regulated to insure that no impacts to the river channel or fish populations occur.

Establishing protections for riparian vegetation.

Recommendations

- **DFG should continue to seek adequate flows and temperatures and the implementation of the above restoration measures for the Yuba River.**

- **DFG will continue to manage the Yuba River as a wild steelhead fishery.** Hatchery steelhead should not be planted in this river.

- **Reduction of the daily bag limit from the current two steelhead per day to one, until population status and angler harvest can be assessed, should be considered.**
  The current status of this population is unknown. Without this knowledge, the angler harvest impacts on the wild population or the need for special regulations cannot be assessed.

AMERICAN RIVER

The steelhead population in the American River is almost entirely supported by Nimbus Hatchery (Fig. 18). At one time, the American River supported one of the best urban steelhead fisheries in the State. The run has declined significantly over the past decade, however. Possible causes of the decline include: adverse temperature and other habitat conditions, rapid flow fluctuations and inadequate releases from Folsom Dam,

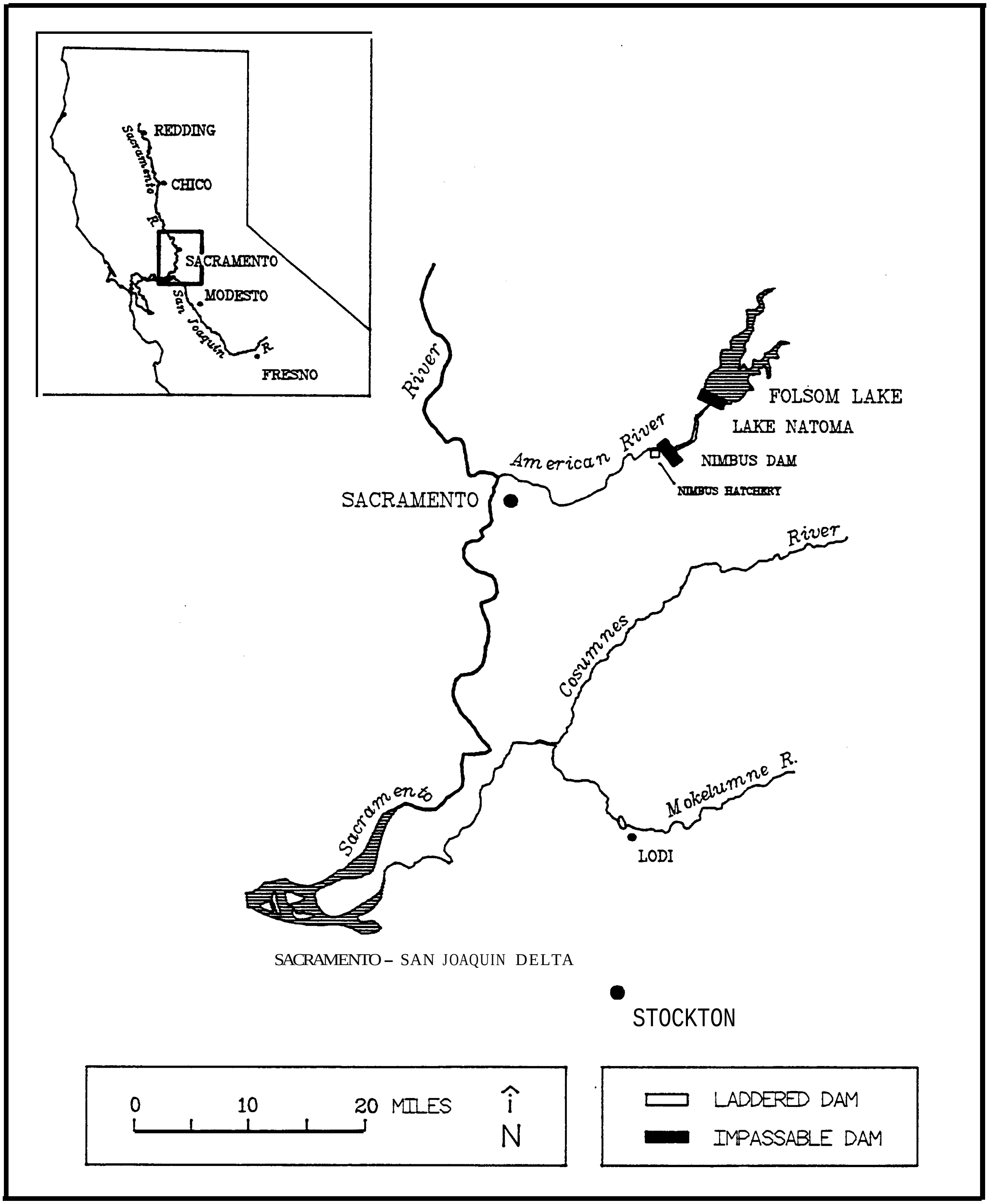


Figure 18. Lower Sacramento River and principal tributaries.

Goals for steelhead management for the lower American River are outlined in the *Steelhead Restoration Plan for the American River* (McEwan and Nelson 1991). Identified measures to restore the steelhead run include:

> Minimum flow standards have been established by judicial action for East Bay Municipal Utility District when they exercise their right to divert American River water. The State Water Resources Control Board should adopt these standards so that they apply to all users of American River water.
>
> Flows during the steelhead spawning and incubation season should be constant so that stranding of redds does not occur.
>
> Investigate the relationship between flow, temperature, and reservoir storage and establish a minimum storage level for Folsom Reservoir so that adequate temperatures during late summer and fall can be provided.
>
> USBR should correct the water temperature problem at Nimbus Hatchery. The hatchery experiences significant problems from high water temperatures almost every year. In the summer of 1992, all rearing steelhead were transported to other rearing facilities because of intolerably high water temperatures.
>
> Investigate the feasibility of restoring steelhead to the upper American River watershed by transporting adults and juveniles around Nimbus and Folsom dams.

Because Folsom Reservoir is relied upon extensively for irrigation and delta salinity control, it is usually drawn down to very low levels by late summer or early fall. This results in depletion of the cold water pool at the bottom of the reservoir, consequently warmer water that is harmful to salmonids is released into the river during summer and fall in most years. This situation is worsened because the water release structure, which releases water to the river via the powerhouse, does not allow maximum conservation of the cold water pool. The structure has several ports at variable water depths, but, because the lowermost seven ports are fused and do not operate individually, cold water from the bottom of the reservoir is released early in the irrigation season during periods when water temperatures in the river are not critical. As a result, the cold water pool is usually exhausted by late summer or early fall, when cold water releases are necessary to maintain suitable temperatures in the river for salmon and steelhead.

Modification of the water release structure to allow release from higher elevations in the reservoir during non-critical periods, thereby conserving the cold water pool, could result in significantly lower river temperatures during the critical late summer and fall period. Hydrologic modeling predicts that October water temperatures at the release site could be as much as 9° F cooler if structural modifications are made that allow for more appropriate operation of the water release structure (Michael Bryan, Senior Scientist, Beak Consultants, pers. comm.) .

Recommendations

- **The water release structure of Folsom Dam should be modified to allow more efficient conservation and** *use* **of the cold water pool in Folsom Reservoir to provide habitat conditions that are more conducive to anadromous fish spawning and survival.**

- **DFG should continue to seek implementation of restoration measures identified in the** *Steelhead Restoration Plan for the American River.*

MOKELUMNE RIVER

The Mokelumne River was once a significant producer of naturally spawned steelhead (Fig. 18). According to creel census data, steelhead were the most sought after fish in the lower Mokelumne River prior to the completion of Camanche Dam (CDFG 1959, as cited in CDFG 1991b). The steelhead run declined significantly following the completion of Camanche Dam in 1963 (CDFG 1991b).

Dam construction, diversions, mining activities, SWP and CVP operations, and impeded passage have caused the decline of the anadromous resources of this river. Flows in the river have been substantially reduced and temperature and water quality have deteriorated from conditions that occurred naturally (CDFG 1982; 1985; 199 lb). The Lower Mokelumne *River Fisheries Management Plan* makes recommendations for instream flows and temperatures standards and other measures needed to maintain and restore steelhead (CDFG 1991b).

A portion of the steelhead reared at the Mokelumne River Fish Installation are planted as catchable trout (about 10 to 16 inches in length) in the lower river to sustain the recreational fishery. Stocking of these fish may be in conflict with the FGC's *Steelhead Rainbow Trout Policy.*

Recommendations

- **Restoration measures identified in the** *Lower Mokelumne River Fisheries Management Plan* **should be implemented as soon as possible.**

- **The Mokelumne River should be managed for ocean-run steelhead. When greater flow releases to support anadromous fish populations are obtained, the present fisheries management strategy should be reevaluated.**

SAN JOAQUIN RIVER

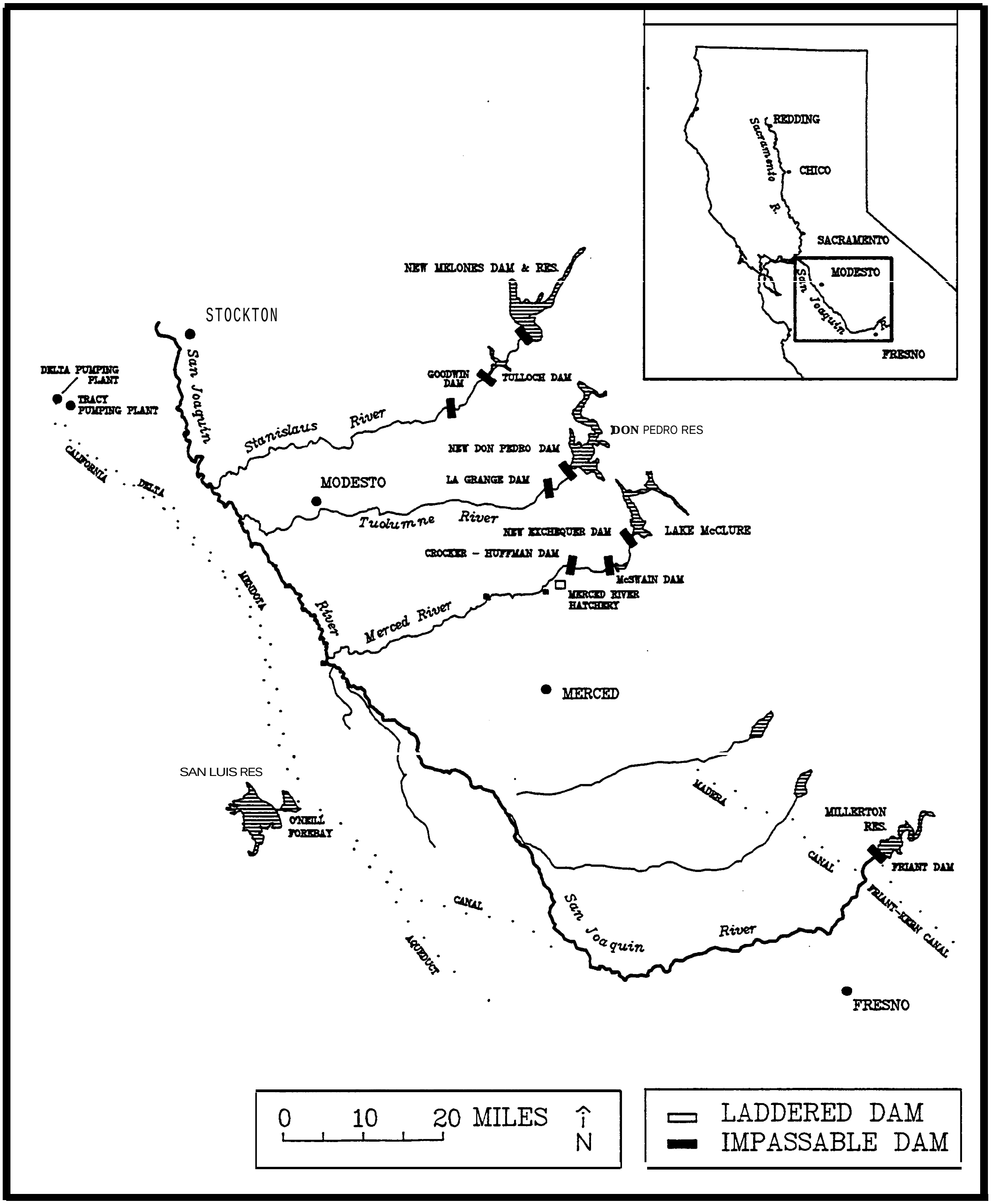
There is no access to the headwaters in any of the tributaries in the San Joaquin River system: all of the major tributaries have impassable dams in the lower reaches (Fig. 19). For this reason,' natural production of steelhead will continue to be limited although it may improve slightly if adequate temperatures and flows currently being sought for chinook salmon are achieved.

It is likely that steelhead could be restored to major San Joaquin River tributaries if temperature and flow standards are established that would provide for juvenile rearing. This would entail operational changes, outlet modifications, and establishment of minimum pools for the major reservoirs so that cool water temperatures could be provided in late-summer and fall. For this effort to be successful, fishways would need to be installed on presently unladdered dams below the large reservoirs to allow access to tailwater habitat.

A salmon and steelhead hatchery has been proposed for the San Joaquin system. The current proposal is to site the hatchery on the Tuolumne River, with an annual production goal of 20,000 yearling steelhead (Bill Loudermilk, DFG Senior Fishery Biologist, pers. comm.).

Recommendations

- **An investigation of reservoir and water operations should be done to determine if it is feasible to provide year-round habitat conditions for rearing steelhead below large reservoirs on the Stanislaus, Tuolumne, and Merced rivers.**



STOCKTON
DELTA PUMPING PLANT
TRACY PUMPING PLANT
CALIFORNIA DELTA
MENDOTA
San Joaquin River
Stanislaus River
NEW MELONES DAM & RES.
GOODWIN DAM
TULLOCH DAM
DON PEDRO RES
NEW DON PEDRO DAM
LA GRANGE DAM
MODESTO
Tuolumne River
NEW EXCHEQUER DAM
LAKE McCLURE
CROCKER - HUFFMAN DAM
McSWAIN DAM
MERCED RIVER HATCHERY
Merced River
MERCED
SAN LUIS RES
O'NEILL FOREBAY
MADERA
CANAL
AQUEDUCT
MILLERTON RES.
FRIANT DAM
FRIANT-KERN CANAL
FRESNO
REDDING
Sacramento R.
CHICO
SACRAMENTO
0 10 20 MILES
N
LADDERED DAM
IMPASSABLE DAM

- **A hatchery program should be implemented if restoration of a steelhead fishery is to be achieved for the San Joaquin River system.**
  The San Joaquin River system may be a good location for the use of a small-scale, portable hatchery facility (see page 128). This type of facility could be used to restore steelhead in tributaries of the San Joaquin system other than the Tuolumne River. There is a need for hatchery and rearing facilities on the Stanislaus and Merced rivers (Bill Loudermilk, pers. comm.). This facility, operated in conjunction with the proposed Tuolumne River hatchery, could be used for egg taking, rearing, and/or imprinting.

CONCLUSION

Steelhead are an important and valued resource to California's citizens, for both angling and non-consumptive users. They are also an important component of the vast biodiversity of the State and are an integral part of many fluvial and estuarine ecosystems. Decline of steelhead populations is but one aspect of the present statewide decline in biodiversity, caused by California's burgeoning human population and the ever-increasing demand on natural resources.

Among the 50 states, California ranks second in numbers of freshwater fish species that are declining (Williams et al. 1989). If anadromous fish stocks are included, however, California clearly leads the nation in species loss and imperilment. Moyle and Williams (1990) showed that two-thirds of the native fish taxa in California is extinct or declining. In the California portion of the Colorado River, 100 per cent of the fish taxa is endangered, threatened, or extinct, and the fish fauna of the once species-rich Klamath and Sacramento-San Joaquin river systems has become severely endangered (Frissell 1993). Other areas which have a high proportion of imperiled species include the Los Angeles basin, the Pajaro-Salinas region, the Owens basin, and the Lahontan basin (Frissell 1993). Of the 2 14 Pacific Salmonid stocks at risk in the contiguous United States, 39 occur in California. Of these, 20 were identified as being at high risk of extinction or possibly already extinct (Nehlsen et at. 1991).

The decline in fishery resources extends beyond the boundaries of the state: Williams et al. (1989) reported that 364 North American freshwater fish species and subspecies are endangered, threatened, or of special concern. This comprises about one-third of the North American freshwater fishes. During this century, fishery scientists have documented the extinction of another 27 species and 13 subspecies: 16 of these since 1964 (Miller et al. 1989). Williams and Miller (1990, as cited in Moyle and Yoshiyama 1994) calculated that 28 % of the known freshwater fish species in North America are extinct or in serious trouble. Decline in North American aquatic species is not limited to fishes: amphibian populations have declined significantly, and the status of aquatic plants and invertebrates is presumably just as bad (Moyle and Yoshiyama 1994).

A common central theme in the literature describing freshwater fish declines in North America is habitat loss and degradation. Aquatic habitat loss and degradation have occurred at an alarming rate over the past several decades, and are continuing. An estimated 50 % of freshwater and estuarine wetlands has been destroyed in North America, and destruction continues at a rate of 290,000 acres per year (American Fisheries Society 1994).

In California, degradation of aquatic habitat and ecosystems has become critical. The Sacramento-San Joaquin river system is a good example of a river system in peril: riparian forests in the Central Valley have been reduced to about 1% of pre-Gold Rush acreage (Abel1 1989); only 6 % of historic riparian habitat of the San Joaquin River in the 25 miles below Friant Dam remains (Furman 1988); over 150 miles of the Sacramento River have banks with riprap (California State Lands Commission 1993); and only 5 % of the historic salmon and steelhead spawning habitat remains (Reynolds et al. 1993).

Most of California's 7,800 rivers are similarly afflicted, some not as bad as the Sacramento-San Joaquin, but many are in far worse condition. A report by the California State Lands Commission "clearly demonstrates the health of California's rivers to be stressed and their viability as sustainable ecosystems in peril" (California State Lands Commission 1993). The report further states: "It should no longer be disputed that there exists an urgent need for state agencies to undertake a comprehensive program of river basin and watershed protection and restoration".

The decline of California's steelhead populations and habitat, as described in this document, is illustrative of this trend of declining biodiversity due to habitat loss and degradation. Steelhead are unique in that they are dependent on essentially all habitats of a river system: the estuary for rearing and acclimation to salt water; the main channel for migration between the ocean and upstream spawning and rearing areas; and the tributaries for spawning and rearing. This dependence on the entire river system explains, in part, why steelhead were one of the first anadromous fish in California to experience dramatic declines in numbers and distribution.

For steelhead, habitat loss and degradation is mostly due to three factors: over-appropriation of stream flows, blocked access to historic spawning and rearing areas, and chronic watershed perturbations that discharge sediment and debris into watercourses. Other factors, such as harvest, high seas gill nets, and adverse ecological conditions in the marine environment may be contributing to the decline but there is little data to suggest that these causes are anything but minor. Land use activities, such as timber harvest and agriculture; and water development, particularly water diversion and dam construction, have eliminated and degraded most of the historic range of steelhead.

Anadromy in salmonids probably evolved to allow the utilization of the resources of two different environments: the ocean, because of its abundant food resources; and freshwater, as a haven from predators where reproduction has a greater chance of success. The large size of steelhead juveniles (compared to salmon) upon entry into the marine environment ensures greater success and survival in the ocean. To achieve this larger size, however, steelhead must rear for longer periods in freshwater. Historically, this evolutionary adaptation has been very successful for steelhead, as evidenced by its widespread Pacific Rim distribution, but now is a factor in the recent decline: most freshwater systems in California are no longer accessible or safe havens for juveniles, due to land and water development impacts. This has affected steelhead more so than salmon because of their longer rearing requirement and their need to spawn at higher elevations in most drainages. The resiliency of rainbow trout and plasticity of behavior patterns have offset this disadvantage somewhat, but populations continue downward nevertheless.

Artificial production has shown some success at increasing steelhead numbers to improve angler success, but has not been successful at replacing fish and habitat lost to water development, or at maintaining genetic diversity. This could be detrimental in the long term, and the scientific literature is replete with papers which describe impacts to wild stocks from artificial supplementation programs. Artificial production cannot approximate nature and the evolutionary processes that have shaped Salmonid behavior and life history. The scientific literature is largely conclusive that hatcheries, although necessary to maintain many anadromous fish runs, cannot achieve long-term survival of an anadromous fish species.

Restoration of steelhead populations is intimately tied to the establishment of a new ethic for management of California's rivers and streams - an ethic that places a much higher priority on the continuance of essential physical, biological, and ecological processes in rivers that are regulated or proposed for development. In simpler terms, rivers need to flow and contain sufficient water to maintain their aquatic biota in good condition. Without this, aquatic habitat will continue to degrade, species will continue to decline, and there will be continued impasses on water usage and development.

Large-scale water development of this century has only been achieved through major advancements in technology. There is a natural tendency to apply this same technological thinking to correct the unanticipated problems caused by water development and to believe that anything can be fixed if we apply enough innovation and technology. Meffe (1992) calls this approach " techno-arrogance" and he believes that the proposed high-tech solutions to the current decline in Pacific Salmonid stocks are doomed to failure because this approach addresses the symptoms, but not the causes, of the decline. He cites, as a prime example, the failure of hatchery supplementation programs to fully mitigate for the effects of water projects. In California, examples of techno-arrogance include engineered minimum flow requirements, ill-conceived spawning gravel augmentation projects, captive breeding programs, trap-and-truck facilities, and 'wild trout" hatcheries.

This is not to say that there isn't a place for technological solutions in anadromous fisheries restoration. Often, it is necessary to correct ongoing problems created by other technological "advances ": the selective withdrawal device proposed for Shasta Dam, for example, is essential to alleviate high water temperatures in the Sacramento River caused by water development.

Perhaps the real danger behind this philosophy is that it can divert attention and forestall real, long-term solutions. All too often, high tech, engineering solutions are proposed in lieu of the one solution that has the highest probability of success: allowing more water to flow down the stream. Unfortunately, because of the monetary value of water in this mostly semi-arid environment, this is often the most difficult solution to implement. However, providing adequate flows, along with rehabilitating watersheds and restoring access to headwaters, is essential to the successful restoration of California's steelhead populations.

LITERATURE CITED

Abell, D. L. 1989. Proceedings of the California riparian systems conference, September, 1988. Gen. Tec. Rep. PSW-110. U.S. Forest Service. 544 pp.

Aguilar, B.C. 1992. Survival, and contributions to the fisheries and spawning escapements made by steelhead produced at Trinity River Hatchery. in K. Urquhart ed. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1989-1990 Season. Inland Fisheries Division, Calif. ept. Fish and Game. pp 136-140

Allendorf, F. W. 1975. Genetic variability in a species possessing extensive gene duplication: genetic interpretation of duplicate loci and examination of genetic variation in populations of rainbow trout. Ph.D. Thesis. Univ. of Washington. 97 pp.

Allendorf, F.W. and F.M. Utter. 1979. Population genetics. in W. Hoar, D. Randall, and J. Brett, eds. Fish Physiology, Vol VIII. Academic Press, New York. p 407-455.

Allendorf, F. W. and S .R. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Trans. Am. Fish. Soc. 9:537-543.

Allendorf, F.W. and N. Ryman. 1987. Genetic management of hatchery stocks. in N. Ryman and F. Utter eds., Population Genetics and Fishery Management. Univ. Wash. Press. Seattle. pp 141-159.

Allendorf, F. W. and R. F. Leary . 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology 2: 170-l 84.

American Fisheries Society. 1994. Vision for North American fisheries in the 21st Century. Fisheries. 19(8). supplement pages l-24.

Anderson, D.G. 1993. Status of summer steelhead trout in Redwood Creek, Redwood National Park, California. Proceedings of the fourth conference on research in California's national parks. National Park Service. transactions and proceedings series 9: l-8.

Anderson, K.R. 1994. Testimony of Keith R. Anderson, Carmel River Hearing, State Water Resources Control Board, Nov. 7 and 8, 1994. Calif. Dept. Fish and Game Exhibit 94-2.

Anonymous. 1953. A plan for the protection and maintenance of salmon and steelhead in the American River, California, together with recommendations for action. Unpublished rpt. prepared jointly by the U.S. Fish and Wildlife Service and California Department of Fish and Game, July 20, 1953. 47 pp.

Bailey, E.D. 1954. Time pattern of 1953-54 migration of salmon and steelhead into the upper Sacramento River. Calif. Dept. Fish and Game unpublished report. 4 pp.

Barnhart, R.A. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) - steelhead. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.60). U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

Behnke, R.J. 1972. The systematics of Salmonid fishes of recently glaciated lakes. J. Fish. Res. Board of Canada. 29(6), 639-671.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph no. 6. 275 p.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program, U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon, 290 pp.

Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. Instream Flow Information Paper 4, U.S. Fish Wild. Serv., FWS/OBS-78/07. 79 pp.

Boydstun, L.B. 1977. California's steelhead program. in T. Hassler and R. VanKirk, eds. Proceedings of the genetic implications of steelhead management symposium, 1977. Calif. Coop. Fish. Res. Unit special report 77- 1. pp. 26-30.

Brown, C. J. 1992. A review of Butte Creek fisheries issues. Bay Delta and Special Water Projects Division, Calif. Dept. Fish and Game. 30 pp.

Brown, R.F. and B.R. Mate. 1983. Abundance, movements, and feeding habits of harbor seals, Phoca vitulina, at Netarts and Tillamook bays, Oregon. NOAA Fishery Bull. 8 l(2): 291-301.

Burgner, R. L., J.T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and origins of steelhead trout *(Oncorhynchus mykiss)* in offshore waters of the north Pacific Ocean. International North Pacific Fisheries Commission. Bull. no. 5 1.

Busby, P. J., O.W. Johnson, T.C. Wainwright, F.W. Waknitz, and R.S. Waples. 1993. Status review for Oregon's Illinois River winter steelhead. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-10, 85 pp.

Byrne, A., T. C. Bjornn, and J.D. McIntyre. 1992. Modeling the response of native steelhead to hatchery supplementation programs in an Idaho river. North American J. Fish. Mgmt. 12:62-78.

Calhoun, A. 1966. Habitat protection and improvement. in A. Calhoun, ed. Inland Fisheries Management. Calif. Dept of Fish and Game. 546 pp.

California Advisory Committee on Salmon and Steelhead Trout. 1988. Restoring the balance. 1988 ann. rpt. 84 pp.

California Department of Fish and Game. 1956. Letter from Robert Paul to L.G. Bennett, Ventura River Municipal Water District. July 19, 1956.

California Department of Fish and Game. 1965. California Fish and Wildlife Plan

California Department of Fish and Game. 1975. An assessment of federal water projects adversely affecting California's salmon and steelhead resources Report . series mandated by the Calif. State Legislature under Senate Concurrent Resolution No. 64. Rpt. no. 4, Cachuma Project. 4 pp.

California Department of Fish and Game. 1982. The Mokelumne River: make-do salmon management. Memo from Fred Meyer to Richard Beland. August 16, 1982.

California Department of Fish and Game. 1984. Memo from Ron Rogers to Yuba River files. March 2, 1984.

California Department of Fish and Game. 1985. Flow problems on the Mokelumne River below Camanche Dam. Memo from Paul Jenson to Bob Fletcher. December 6, 1985.

California Department of Fish and Game. 1990. Central Valley Salmon and Steelhead Restoration and Enhancement Plan. 115 pp.

California Department of Fish and Game. 1991a. Lower Yuba River fisheries management plan. Stream Evaluation Report No. 91-1. 197 pp.

California Department of Fish and Game. 1991b. Lower Mokelumne River Fisheries Management Plan. Streamflow Requirements Program. 239 pp.

California Department of Fish and Game. 1992a. Status report: California salmon. Report to the Fish and Game Commission.

California Department of Fish and Game. 1992b. Memo from John Hayes to Tim Farley. June 10, 1992.

California Department of Fish and Game. 1992c. Memo from Banky Curtis to Tim Farley. September 4, 1992.

California Department of Fish and Game. 1992d. Stream survey report, Santa Rosa Creek. 5 PP.

California Department of Fish and Game. 1993a. Memo from Chuck Knutson to Tim Farley. April 29, 1993.

California Department of Fish and Game. 1993b. Appeal and statement of reasons in support of the appeal of the California Department of Fish and Game, January 11, 1993.

California Department of Fish and Game. 1993c. Memo from Maurice Cardenas to Dwayne Maxwell. March 1, 1993.

California Department of Fish and Game. 1994a. Memo from Maurice Cardenas to Dwayne Maxwell. April 6, 1994.

California Department of Fish and Game. 1994b. Comments on Draft Environmental Impact Statement, Rangeland Reform '94. Letter from to Boyd Gibbons to Bureau of Land Management. September 6, 1994.

California Department of Forestry and Fire Protection. 1993. An evaluation of Option 9 of the Federal Forest Plan as it relates to northwestern California. Strategic Planning Program. 65 pp.

California Department of Parks and Recreation 1992. Memo from William Tippets to Daniel Preece. October 14, 1992.

California State Lands Commission. 1993. California's rivers, a public trust report. 334 pp.

Chamberlin, T.W., R.D. Harr, and F.H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. in W. Meehan, ed. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19: 181-206.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Trans. Am. Fish. Soc. 115:726-735.

CH2M Hill. 1985. Klamath River Basin Fisheries Resource Plan. Redding, Ca.

Clanton, D.A. and J.W. Jarvis. 1946. Field inspection trip to the Matilija-Ventura watershed in relation to the construction of the proposed Matilija Dam. California Division of Fish and Game, Field Correspondence. May 8, 1946.

Collins, B.W. and C.E. Wilson. 1994. Life history, distribution, run size, and angler harvest of steelhead in the South Fork Trinity River basin. in K. Urquhart and R. Kano eds. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1991- 1992 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 56-102.

Cornstock, R. 1992. Santa Clara River steelhead restoration assessment. U.S. Fish and Wildlife Service. Fishery Resource Office, Olympia Washington.

Cooper, R., and T.H. Johnson. 1992. Trends in steelhead *(Oncorhynchus mykiss)* abundance in Washington and along the Pacific coast of North America. Washington Department of Wildlife, Fisheries Management Division. Report No. 92-20. 90 pp.

Coots, M. 1973. A study of juvenile steelhead, *Salmo gairdnerii gairdnerii* Richardson, in San Gregorio Creek and lagoon, San Mateo County, March through August, 1971. California Dept. of Fish and Game Anadromous 'Fisheries Branch Admin. Rpt. 73-4.

Entrix, Inc. 1993. Results of fish passage monitoring at the Vern Freeman Diversion Facility, Santa Clara River. Report prepared for United Water Conservation District.

Evans, W. A. 1950. A preliminary analysis of the fisheries value of the Santa Ana River drainage, California. Calif. Div. of Fish and Game. unpublished rpt. 19 pp.

Everest, F. H. 1973. Ecology and management of summer steelhead in the Rogue River. Fishery Research Rpt. No. 7. (Project AFS 31 Final Rpt.) Oregon State Game Commission. 48 pp.

Flosi, G. and F.L. Reynolds. 1994. California Salmonid stream habitat restoration manual. 2nd edition. Calif. Dept. of Fish and Game.

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Rpt of the Forest Ecosystem Management Assessment Team.

Franklin, R.F. and S.S. Dobush. 1989. Malibu Creek steelhead habitat assessment. Report prepared for California Trout, Inc. by Entrix Inc.

Frissell, C. A. 1993. Topology of extinction and endangerment of native fishes in the Pacific northwest and California (U.S.A.). Conservation Biology. 7(2):342-354.

Fry, D.H. 1973. Anadromous fishes of California. Calif Dept. of Fish and Game. 112 pp.

Furman, D. 1989. San Joaquin river riparian habitat below Friant Dam: preservation and restoration. Proceedings of the California riparian systems conference, September, 1988. Gen. Tec. Rep. PSW-110. U.S. Forest Service. 544 pp.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. in W. Meehan, ed. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19: 18 l-206.

Futuyma, D. J. 1986. Evolutionary Biology. Sinauer and Assoc, Inc. Massachusetts. 600 pp.

Gadomski, D.M. and J.A. Hall-Griswold. 1992. Predation by northern squawfish on live and dead juvenile chinook salmon. Trans. Am. Fish. Soc. 121:680-685.

Gall, G.A.E., B. Bentley, and R.C. Nuzum. 1990. Genetic isolation of steelhead rainbow trout in Kaiser and Redwood creeks, California. Calif. Fish and Game. 76:2 16-223.

Glaze, J.D., S.H. Kramer, and Barnhart, R.A. 1991. Temporal utilization by naturally produced steelhead juveniles of various habitat types within selected South Fork Trinity River tributaries. Final Rpt. Federal Aid Project F-51-R, subproject IX, Study 11, Job 3. 65 pp.

Goodman, M.L. 1990. Preserving the genetic diversity of Salmonid stocks: a call for federal regulation of hatchery programs. Environmental Law. 20: 11 l- 166

Graybill, M.R. 1981. Haul out patterns and diet of harbor seals, *Phoca vitulina*, in Coos County, Oregon. Masters Thesis. Univ. of Oregon. 55 pp.

Hallock, R.J., W.F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmo *gairdnerii gairdnerii)* in the Sacramento River system. Calif. Dept. Fish and Game Fish Bull. No. 114. 74 pp.

Hallock, R. J. 1989. Upper Sacramento River steelhead, *Oncorhynchus mykiss),* 1952-1988. Rpt to the Fish and Wildlife Service. 85 pp.

Hanson, L.C. 1993. The foraging ecology of harbor seals, *Phoca vitulina,* and California sea lions, *Zalophus californianus,* at the mouth of the Russian River, California. Masters Thesis, Sonoma State Univ. 70 pp.

Hard, J.J., R.P. Jones, M.R. Delarm, and R.S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-2, 56 pp.

Harvey, C.D. Adult steelhead counts in Mill and Deer creeks, Tehama County, October 1993 - June, 1994. Calif. Dept. Fish and Game. Inland Fisheries Admin. Rpt. No. 95-3 9 pp.

Healey , M.C. 1991. Life history of chinook salmon *(Oncorhynchus tshawytscha).* in *C.* Groot and L. Margolis, eds. Pacific salmon life histories. Univ. British Columbia Press. Vancouver, BC.

Helle, J.H. 198 1. Significance of the stock concept in artificial propagation of salmonids in Alaska. Can. J. Fish and Aquat. Sci. 38:1665-1671.

Heubach, B., M. Lau, and E. Miller. 1992. Annual run-size, harvest, and spawner escapement estimates for Trinity River basin chinook and coho salmon and steelhead. in K. Urquhart and R. Carpenter eds. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1990-1991 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 93-145.

Higgins, P. 1991. Southern California steelhead recovery assessment: San Mateo Creek and the Santa Margarita River. Prepared for the South Coast Chapter of Trout Unlimited. 26 pp.

Higgins, P., S. Dobush, and D. Fuller. l992. Factors in northern California threatening stocks with extinction. Humboldt Chapter American Fisheries Society. 26 pp.

Hilborn, R. 1992. Hatcheries and the future of salmon in the northwest. Fisheries. 17:5-8.

Hindar, K., N.Ryman, and F. Utter. 1991. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci. 48:945-957.

Hodges, J.K., R.A. Barnhart, and E.J. Loudenslager. 1989. Analysis of genetic variation in steelhead trout *(Oncorhynchus mykiss)* populations in the South Fork Trinity River, California. Final Contract Rpt. Calif. Dept. Fish and Game contract no. FG-7525. 49 pp.

Hooper, D.R. 1973. Evaluation of the effects of flows on trout stream ecology. Dept. of Eng. Res., Pacific Gas and Electric Co. Emeryville, Calif. 97 pp.

Hopelain, J.S. 1987. Age, growth, and life history of Klamath River basin steelhead *(Salmo gairdnerii) as* determined from scale analysis. Calif. Dept. Fish and Game DRAFT Administrative Rpt . 87-.

Hubbs, C. L. 1946. Wandering of pink salmon and other Salmonid fishes into southern California. Calif. Fish and Game. 32(2):81-85.

Hynes, J.D., E.H. Brown Jr., J.H.Helle, N. Ryman, and D.A. Webster. 198 1. Guidelines for the culture of fish stocks for resource management. Can. J. Fish. Aquat. Sci. 38: 1867-1876.

Irizarry, R. **A.** 1991. Model Steelhead Stream Demonstration Project. Shasta-Trinity National Forests.

Jameson, R.J. and K.W. Kenyon. 1977. Prey of sea lions in the Rogue River, Oregon. J. Mammal. 58(4):672.

Jensen, D.B., M. Torn, and J. Harte. 1990. In our own hands: a strategy for conserving biological diversity in California. C.P.S. Report. Publication of the California Policy Seminar.

Jones and Stokes Associates. 1993. Phase I project description and background hydrology report for the Hearst Corporation water rights applications 27126 and 27212. Report prepared for the Hearst Corporation. 16 pp.

Jonsson, B. 1985. Life history patterns of freshwater resident and sea-run migrant brown trout in Norway. Trans. Amer. Fish. Soc. 114: 182-194.

Keegan, T.P. 1990. Malibu Creek/Santa Monica Mountains steelhead investigations. Report prepared for California Trout, Inc. by Entrix Inc.

Kesner, W .D. and R. A. Barnhart. 1972. Characteristics of the fall-run steelhead trout *(Salmo gairdneri gairdneri)* of the Klamath River system with emphasis on the half-pounder. Calif. Fish and Game. 58(3):204-220.

Klamath River Basin Fisheries Task Force. 1991. Long Range plan for the Klamath River Basin Conservation Area Fishery Restoration, Program.

Kondolf, M.G. and W.V.G. Matthews. 1993. Management of coarse sediment on regulated rivers. Univ. Cal. Davis Water Resources Center Rpt. No. 80. 128 pp.

Krueger, C.C., A.J. Gharrett, T.R. Dehring, and F.W. Allendorf. 1981. Genetic aspects of fisheries rehabilitation programs. Can J. Fish. and Aquat. Sci. 38: 1877-1881.

Lau, M., B. Heubach, and E. Miller. 1994. Annual run-size, harvest, and spawner escapement estimates for Trinity River basin chinook and coho salmon and steelhead. in K. Urquhart and R. Kano eds. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1991- 1992 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 103-167.

Law/Crandall, Inc. 1994. Report of geotechnical and environmental study, Malibu Creek steelhead restoration project, Malibu area, Los Angeles County, California. Report prepared for the California Division of the State Architect. 22 pp.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout *(Salmo gairdneri):* evidence for partial reproductive isolation. Can. J. Fish. Aquat. Sci. 41:1454-1462.

Leider, S.A. 1986. Comparative life history characteristics of hatchery and wild steelhead trout *(Salmo gairdneri)* of summer and winter races in the Kalama River, Washington. Can. J. Fish. Aquat. Sci. 43:1398-1409.

Leidy, R.A. 1991. Observation of steelhead trout, *Oncorhynchus mykiss* within the Ventura River Estuary, Ventura County, California. Memorandum to B. Harper, USFWS, Laguna Niguel. May 8, 1991.

Leitritz, E. and R.C. Lewis. 1980. Trout and salmon culture (hatchery methods). Calif. Fish. Bull. no. 164. Univ. of Calif.

Light, J.T. 1987. Coastwide abundance of North American steelhead trout. (Document submitted to annual meeting of the INPFC, 1987) FRI-UW-8710. Fish. Res. Inst., Univ. Washington. Seattle. 18 pp.

Light J.T., S. Fowler, and M.L. Dahlberg. 1988. High seas distribution of North American steelhead as evidenced by recoveries of marked or tagged fish. (Document submitted to the International North Pacific Fisheries Commission.) FRI-UW-8816. Fisheries Research Institute, University of Washington, Seattle. 21 pp.

Light, J.T., C.K. Harris, and R.L. Burgner. 1989. Ocean distribution and migration of steelhead *(Oncorhynchus mykiss,* formerly *Salmo gairdneri).* (Document submitted to the International North Pacific Fisheries Commission.) FRI-UW-8912. Fisheries Research Institute, University of Washington, Seattle. 50 pp.

Lungren, D.E., C.W. Getz, and E. Walz. 1995. Petition for reconsideration. In the matter of the four complaints filed against the California-American Water Company; Order No. WR 95-10. Filed with the State Water Resources Control Board, Aug. 7, 1995.

Marston, D. 1992. June-July 1992 stream survey report of lower Scott Creek, Santa Cruz County. Calif. Dept. of Fish and Game Report.

Martin, J., J. Webster, and G. Edwards. 1992. Hatcheries and wild stocks: are they compatible? Fisheries. 17(1):4

McEwan, D. and J. Nelson. 1991. Steelhead Restoration Plan for the American River. Calif. Dept. of Fish and Game. 40 pp.

Meehan, W.R. 1991. Introduction and overview. in W. Meehan, ed. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19: l- 15.

Meffe, G.K. 1986. Conservation genetics and the management of endangered fishes. Fisheries. 11: 14-23.

Meffe, G.K. 1992. Techno-arrogance and halfway technologies: salmon hatcheries on the Pacific coast of North America. Conservation Biol. 6:350-354.

Menchen, R.S. 1980. Estimated freshwater sport catch of Coleman Hatchery yearling steelhead, *Salmo gairdnerii,* in 1973. Calif. Dept. of Fish and Game, Anadromous Fisheries Branch Office Report. 6 pp.

Mendocino County. 1992. Mendocino County Lake Mendocino Hatchery Facility Management Plan. 3 pp.

Mendocino County Resource Conservation District. 1992. Garcia River watershed enhancement plan. Prepared for the California State Coastal Conservancy.

Meyer Resources, Inc. 1988. Benefits from present and future salmon and steelhead production in California. Report to the California Advisory Committee on Salmon and Steelhead. 78 pp.

Miller, R.R., J.D. Williams, and J.E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries. 14(6):22-38.

Miller, W.H., T. *C.* Coley, H.L. Burge, and T.T. Kisanuki. 1990. Analysis of salmon and steelhead supplementation: emphasis on unpublished reports and present programs. U. S . Dept. of Energy, Bonneville Power Admin. Tech. Rpt. 1990. Project No. 88-100.

Mills, T. J. and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. Calif. Dept. Fish and Game. Inland Fisheries Division Technical Report. DRAFT. 70 pp.

Mills, T.J. and C.E. Wilson. 1991. Life history, distribution, run size, and angler harvest of steelhead in the South Fork Trinity River basin. in R. Carpenter and K. Urquhart eds. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1988- 1989 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 34-51.

Moffett, J.W. and S.H. Smith. 1950. Biological investigations of the fishery resources of the Trinity River, California. Special Scientific Rpt. No. 12. U.S. Fish and Wildlife Service. 71 pp.

Moore, M.M. 1980a. Factors influencing the survival of juvenile steelhead rainbow trout (Salmo *gairdneri gairdneri)* in the Ventura River, California. Masters Thesis. Humboldt State Univ. 82 pp.

Moore, M.M. 1980b. An assessment of the impacts of proposed improvements to the Vern Freeman Diversion on anadromous fishes of the Santa Clara River system, Ventura County California. Ventura County Environmental Resources Agency Contract no. 670.

Moyle, P.B. 199 la. Conservation of native fishes: a general proposal. unpublished. 12 pp.

Moyle, P.B. 1991b. Written correspondence to Steve Parmenter, DFG. 2/27/91.

Moyle, P.B. and J.E. Williams. 1990. Biodiversity loss in the temperate zone: decline of the native fish fauna of California. Conservation Biology. 4(3):275-284

Moyle, P.B. and R.M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries. 19(2):6-l 8.

Murphy, G.I. 1946. A survey of Stony Creek, Grindstone Creek, and Thomes Creek drainages in Glenn, Colusa, and Tehama counties, California. Calif. Dept. Fish and Game, Anadromous Fisheries Branch Administrative Report No. 46-15. 9 pp.

National Council on Gene Resources. 1982. Anadromous Salmonid genetic resources: an assessment and plan for California. California Gene Resources Program, Berkeley. 168 pp.

Needham, P.R., O.R. Smith, and H.A. Hanson. 1941. Salmon salvage problems in relation to Shasta Dam, California, and notes on the biology of the Sacramento River salmon. Trans. Amer. Fish. Soc. 17th annual meeting.

Needham, P.R., and R. Gard. 1959. Rainbow trout in Mexico and California with notes on the cutthroat series. Univ. Cal. Publications in Zoology. 67(1): l- 124.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries. 16(2):4-2 1.

Nelson, J. n.d. South central coastal stream coho salmon and steelhead trout population inventory and habitat assessment. Fed. Aid Sport Fish Rest. Act 1992-93 annual performance report. Proj. no. F-51-R-5; Study no. 21; Job no. 1. 52 pp.

Nelson, K., and M. Soule. 1987. Genetical conservation of exploited fishes. in N. Ryman and F. Utter eds., Population Genetics and Fishery Management. Univ. Wash. Press. Seattle. pp 345-368.

Nielsen, J. L. 1994. Molecular genetics and stock identification in Pacific salmon *(Oncorhynchus* spp .) . Ph.D. Thesis. Univ. of California, Berkeley. 167 pp.

Nielsen, J.L, C.A. Gan, J.M. Wright, D.B. Morris, and W.K. Thomas. Biogeographic distributions of mitochondrial and nuclear markers for southern steelhead. Molecular Marine Biology and Biotechnology (accepted for publication).

Oregon Dept. of Fish and Wildlife. 1986. Steelhead management plan 1986-1992.

Oregon Natural Resources Council and 14 others. 1994. Petition for a rule to list steelhead trout as threatened or endangered under the Endangered Species Act and to designate critical habitat. 133 pp.

Pacific Watershed Associates. 1994. Action plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for U.S. Bureau of Reclamation and the Trinity River Task Force.

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. (Washington Sea Grant Program, Seattle), 179 pp.

Pella, J., R. Rumbaugh, L. Simon, M. Dahlberg, S. Pennoyer, and M. Rose. 1991 (in press). Incidental and illegal catches of salmonids in North Pacific driftnet fisheries. (INPFC Doc.) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA. 48 pp.

Petersen, J.H., D.M. Gadomski, and T.P. Poe. 1994. Differential predation by northern squawfish *(Ptychocheilus oregonensis)* on live and dead juvenile salmonids in the Bonneville Dam tailrace (Columbia River). Can. J. Fish. Aquat. Sci. 5 1: 1197-1204.

Platts, 1991. Livestock grazing. in W. Meehan, ed. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19: 329-423.

Pollard; H.A., and T.C. Bjornn. 1973. The effects of angling and hatchery trout on the abundance of juvenile steelhead trout. Trans. Amer. Fish. Soc. 4:745-752.

Puckett, L.K. and N.A. Villa. 1985. Lower Santa Clara River steelhead study. Calif. Dept. of Fish and Game. Final Contract Rpt. Interagency Agreement no. B54179.

Quinn, T.P. 1984. Homing and straying in Pacific salmon. in J. McCleave, G. Arnold, J Dodson, and W. Neill, eds. Mechanisms of migration in fishes. Plenum press. New York. p. 357-362.

Rathbun, G.B., K. Worcester, D. Holland, and J. Martin. 1991. Status of declining aquatic reptiles, amphibians, and fishes in the lower Santa Rosa Creek, Cambria, California. Report prepared for Greenspace. 21 pp.

Reeves, G.H., J.D. Hall, T.D. Roelofs, T.L. Hickman, and C.O. Baker. 1991. Rehabilitating and modifying stream habitats. in W. Meehan, ed. Influences of forest and rangeland management on Salmonid fishes and their habitats. American Fisheries Society Special Publication 19:5 19-558.

Reisenbichler, R. R. and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, Salmo *gairdneri.* J. Fish. Res. Board Can. 34: 123-128.

Reisenbichler, R.R., and S.R. Phelps. 1989. Genetic variation in steelhead (Salmo *gairdneri)* from the north coast of Washington. Can. J. Fish. Aquat. Sci. 46:66-73.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Or, General Technical Report PNW-96, 54 pp.

Reynolds, F. L., Mills, T. J., Benthin, R., and A. Low. 1993. Restoring Central Valley streams: a plan for action.

Rhoades, R.R. 1991. The world's food supply at risk. National Geographic. 179:75-105.

Rich, W. M. 1939. Local populations and migration in relation to the conservation of Pacific salmon in the western states and Alaska. Contribution no. 1, Oregon Fish Commission.

Roelofs, T.D. 1983. Current status of California summer steelhead (Salmo *gairdneri)* stocks and habitat, and recommendations for their management. Report to U.S. Forest Service, Region 5. 77 pp.

Roffe, T.J. and B.R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. J. Wildl. Manage. 48(4); 1262-1274.

Royal, L.A. 1972. An examination of the anadromous trout program of the Washington State Game Department. Washington Dept. of Game. 176 pp.

Sacramento River Information Center. 1993. Toxic pollution of the Sacramento River. Research Rpt. No. 1. 14 pp.

Scarnecchia, D.L. 1988. Salmon management and the search for values. Can. J. Fish. Aquat. Sci. 45. 2042-2050.)

Scheffer, T.H. and C.C. Sperry. 1931. Food habits of the Pacific harbor seal, *Phoca richardii*. J. Mammal. 12:214-226.

Schramm, H.L., M.L. Armstrong, N.A. Funicelli, D.M. Green, D.P. Lee, R.E. Manns B. D. Taubert, and S. J. Waters. 199 1. *The* status of competitive sport fishing in North America. Fisheries. 16(3):4-12.

Shapovalov, L. 1939. Recommendations for management of the fisheries of the Eel River drainage basin, California. Bureau of Fish Conservation, Calif. Div. of Fish and Game. 43 pp.

Shapovalov, L. 1944a. Preliminary report on the fisheries of the Russian River system, California. Calif. Div. of Fish and Game, Inland Fisheries Branch Admin. Rpt. 44-13. 8 pp.

Shapovalov, L. 1944b. Preliminary report on the fisheries of the Santa Ynez River system, Santa Barbara County, California. Calif. Div. of Fish and Game, Inland Fisheries Branch Admin. Rpt. 44-14. 22 pp.

Shapovalov, L. 1945. Report on relation to maintenance of fish resources of proposed dams and diversions in Santa Barbara County, California. Calif. Div. of Fish and Game, unpublished report. 11 pp.

Shapovalov, L. 1946. Observations on steelhead spawning and water conditions in Santa Ynez River, Santa Barbara County, March, 1946. Calif. Div. of Fish and Game, Field Correspondence memo. 2 pp.

Shapovalov, L. 195 1. A remarkable sea journey by a rainbow trout (*Salmo gairdnerii*) of "interior stock". Calif. Fish and Game. 37(4): 489-490.

Shapovalov, L. and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri*) and silver salmon *(Oncorhynchus kisutch)* with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dept. Fish and Game, Fish Bull. No. 98. 373 pp.

Sibbald, G.F., S. Engblom, and V. Whitman. 1994. Steelhead surveys in six southern California Coastal streams: El Jaro Creek, Gaviota Creek, North Fork Matilija Creek, Ventura River, San Antonio Creek, and Malibu Creek, 1993. Calif. Dept. Fish and Game, Inland Fisheries Division Admin. Rpt. DRAFT. 36pp.

Skinner, J.E. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay Area. Calif. Dept. Fish and Game Water Projects Branch Rpt. no. 1.

Smith, G.E. 1986. Instream flow requirements, anadromous salmonids spawning and rearing, Lagunitas Creek, Marin County. Calif. Dept. Fish and Game Stream Evaluation Report No. 86-2. 37 pp.

Smith, J.J. 1986. Southern steelhead. in The natural (and unnatural) history of California trout (Abstracts of papers presented at The natural (and unnatural) history of California trout symposium, January, 1985). American Fisheries Society, California/Nevada Chapter.

Smith, J.J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio creek estuary/lagoon systems, 19851989. San Jose State Univ. Interagency Agreement 84-04-324. 38 pp.

Snider, W. M. 1974. A survey of barriers to fish migration - Chorro Creek - San Luis Obispo County. CDFG Region 3 report.

Snider, W.M. 1983. Reconnaissance of the steelhead resource of the Carmel River Drainage, Monterey County. Calif. Dept. Fish and Game, Environmental Services Branch, Admin. Report No. 83-3, 41 pp.

Staley, J.R. 1976. American River steelhead, *Salmo gairdnerii gairdnerii*, management, 1956-1974. Calif. Dept. Fish and Game, Anadromous Fisheries Branch, Admin. Report No. 76-2, 41 pp.

Steiner Environmental Consulting. 1993. Potter Valley Project Monitoring Program: Effects of operations on upper Eel River anadromous salmonids. 1991/ 1992 Progress Report.

Stickney , R. R. 1994. Use of hatchery fish in enhancement programs. Fisheries. 19(5): 6- 13.

Swift, C.C., T.R. Haglund, M. Ruiz, and R.N. Fisher. 1993. The status and distribution of the freshwater fishes of southern California. Bull. Southern Calif. Acad. Sci. 92(3). pp. 101-167.

Taylor, T. L. 1992. An overview of estuaries, lagoons, and river mouths along the California coast. in C. Tuss, ed. Proceedings of the estuary and ocean productivity workshop, 1990. 8 pp.

Tehama Flyfishers. 1992. Letter from C. Dejournette to Boyd Gibbons. August 14, 1992.

Thompson, K. 1972. Determining stream flows for fish life. in Proceedings, Instream Flow Requirement Workshop. Pac. N.W. River Basin Comm., Vancouver, Wash. pp. 31-50.

Thorpe, J. E. 1994. Salmonid flexibility: responses to environmental extremes. Trans. Amer. Fish. Soc. 123:606-612.

Thorpe, J.E., and J.F. Koonce (with D. Borgeson, B. Henderson, A. Lamsa, P.S. Maitland, M.A. Ross, R.C. Simon, and C. Walters). 1981. Assessing and managing man's impact on fish genetic resources. Can. J. Fish. Aquat. Sci. 38:1899-1907.

Titus, R.G., D. C. Erman, and W.M. Snider. History and status of steelhead in California coastal drainages south of San Francisco Bay. Hilgardia (accepted for publication)

Trautwein, B.G. 1994. Letter to Tom Keegan, Entrix. March 3, 1994.

Trinity River Basin Fish and Wildlife Task Force. 1982. Trinity River basin fish and wildlife management program.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. Upper Sacramento River Fisheries and Riparian Habitat Management Plan. Rpt. Prepared for the Resources Agency, State of California. 158 pp.

U.S. Dept. of Agriculture and U.S. Dept. of Interior. 1993. Supplemental Environmental Impact Statement on Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl.

U.S. Fish and Wildlife Service. 1994. Restoration of the mainstem Trinity River background report. Trinity River Restoration Program. 14 pp.

U.S. Forest Service. 1985. Model steelhead stream demonstration project management plan. Shasta-Trinity and Six Rivers National Forests.

Ventura River Municipal Water District. 1956a. Letter from L. G. Bennett to Robert Paul, DFG. June 30, 1956.

Ventura River Municipal Water District. 1956b. Letter from L.G. Bennett to G. Ray Rolin, USBR. June 30, 1956.

Waples, R.S. 1991. Definition of "species " under the Endangered Species Act: application to Pacific Salmon. NOAA Technical Memorandum NMFS F/NWC-194. U.S. Dept. of Commerce.

Waples, R.S., G.A. Winans, F.M. Utter, and C. Mahnken. 1990. Genetic approaches to the management of pacific salmon. Fisheries. 15(5): 19-25.

Wetlands Research Associates, Inc. 1992. Ventura River estuary enhancement - existing conditions. Report prepared for City of San Buenaventura, Calif. Dept. Parks and Rec., and Calif. State Coastal Cons. 155 pp.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Balderas, J.D. Williams, M. Navarro-Mendoza, D.E. McAllister, and J.E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6):2-20.

Wilson, C.E. and B.W. Collins. 1992. Life history, distribution, run size, and angler harvest of steelhead in the South Fork Trinity River basin. in K. Urquhart and R. Carpenter eds. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1990-1991 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 50-92.

Wilson, C.E. and T.J. Mills. 1992. Life history, distribution, run size, and angler harvest of steelhead in the South Fork Trinity River basin. in K. Urquhart ed. Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project, 1989- 1990 Season. Inland Fisheries Division, Calif. Dept. Fish and Game. pp 44-81.

Wilson, G.M., W.K. Thomas, and A.T. Beckenbach. 1985. Intra- and inter-specific mitochondrial DNA sequence divergence in Salmo: rainbow, steelhead, and cutthroat trouts. Can. J. 2001. 63: 2088-2094.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific coast of North America. J. Fish. Res. Board of Canada. 23(3), 365-393.

Wright, S. 1993. Fishery management of wild Pacific salmon stocks to prevent extinctions. Fisheries. 18(5):3-4.